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On Vision and Language Interaction in Negation Processing

The Real-Time Interpretation of Sentential Negation in Typically Developed and Dyslexic Adults

IN *CO-TUTELLE DE THÉSE* WITH GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

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Abstract

Despite the fact that sentential negation is a widely-investigated linguistic phenomenon, psycholinguistic research has so far provided conflicting evidence as concerns core aspects of the processing: in particular, the timing and the mode of negation integration into sentence meaning are still under debate, as well as the role of the argument of negation (i.e., the negated information) in the interpretation process.

The present work aims at contributing to this theoretical debate on negation processing through the deployment of an identification task in a visual world set-up (i.e., with eye-recording). This methodology allows us to investigate the online processing of negative sentences compared to their affirmative counterpart by providing relevant insights on how linguistic and visual sources of information interact during the real-time comprehension process. Strikingly, unlike in previous studies on negation processing, we manipulate the visual prominence of the negated information by varying the number of pictures in which it is depicted in the visual scenario: by doing so, we can understand whether the negated information is actively exploited by the parser during the interpretation process, and what the effect of its visual prominence is on the processing costs of negative sentences.

In the first study, a group of 62 typically developed Italian adults have been tested. The results were strongly in compliance with a non-incremental view of negation processing, along the lines of the Two-Step Simulation Hypothesis (Kaup et al. 2007). We have provided compelling evidence that: i) the processing of negative sentences is inherently more demanding than that of affirmatives also when an adequate context of utterance is provided; ii) the visual prominence of the negated information has a facilitating effect on sentence interpretation, by reducing the processing costs of the negative sentences compared to the affirmative baseline.

In the second part of the work, we have extended the investigation to a group of Italian dyslexic adults: in fact, while researchers have exstensively studied the processing of sentential negation in populations of normal readers, only a few and quite recent studies have been conducted to investigate negation processing in dyslexic subjects. Previous research has reported an increased difficulty in the interpretation of negative sentences by dyslexic subjects (Vender & Delfitto 2010, Scappini et al. 2015) and poor readers (Hu et al. 2018) compared to normal readers, arguably attributable to limitations in participants' working memory capacity, which prevent them from accomplishing too demanding linguistic operations. Nonetheless, these works provide controversial evidence on whether, within a non-incremental framework of negation processing, sentential negation constitutes a specific source of processing complexity for dyslexics, or whether dyslexics are affected by a more general computational impairment.

A follow-up study with dyslexic adults and age-matched controls has been conducted to disentangle the relationship between dyslexia, negative sentence processing and working memory capacity. The results replicate the findings of the first experiment: similarly to normal readers, dyslexics adopt a non-incremental strategy of negation processing, and the visual prominence of the negated information has a positive effect on the computation of negative sentences. Furthermore, we also find that dyslexics faced a more wide-spread impairment in the interpretation of both affirmative and negative sentences compared to controls, which cannot be completely attributable to the higher processing costs of negation.

Abstrakt

Obwohl die Satznegation ein umfassend untersuchtes Sprachphänomen ist, hat die Psycholinguistik bisher widersprüchliche Erkenntnisse zu zentralen Aspekten ihrer Verarbeitung geliefert. Insbesondere der genaue Zeitpunkt und die Art der Integration der Negation in die Satzbedeutung sind noch umstritten. Dasselbe gilt auch für die Rolle des Negationsarguments (d.h. der negierten Information) im Interpretationsprozess.

Die vorliegende Arbeit will einen Beitrag zur theoretischen Debatte über die Negationsverarbeitung leisten, indem eine Erfassungaufgabe in einem Visual-World-Paradigma (d.h. unter Messung der Augenbewegung) gestellt wird. Diese Methodik erlaubt es uns, die Online-Verarbeitung negativer Sätze im Vergleich zu ihren affirmativen Gegenstücken zu untersuchen und so relevante Erkenntnisse darüber zu gewinnen, wie linguistische und visuelle Informationsquellen während des Echtzeit-Verstehensprozesses interagieren. Innovativ, und anders als in früheren Studien zur Negationsverarbeitung, manipulieren wir hier den Einfluss der negierten Information, indem wir die Anzahl der Bilder, in denen sie repräsentiert wird, variieren. Auf diese Weise können wir erkennen, ob die negierte Information während des Interpretationsprozesses aktiv vom Parser genutzt wird und welchen Effekt ihre visuelle Prominenz auf den Verarbeitungsaufwand negierter Sätze hat.

In der ersten Studie wurde eine Gruppe von 62 normal entwickelten italienischen Erwachsenen getestet. Die Ergebnisse entsprachen einer nichtinkrementellen Auffassung von Negationsverarbeitung im Sinne der Zwei-Simulationen-Hypothese (Kaup et al. 2007). Wir haben überzeugende Belege dafür geliefert, dass: i) die Verarbeitung negativer Sätze inhärent anspruchsvoller ist als die von affirmativen, auch wenn der Äußerungskontext adäquat etabliert ist; ii) die visuelle Hervorhebung von negierter Information die Satzinterpretation einfacher macht, indem sie den Verarbeitungsaufwand von den negativen Sätzen im Vergleich zum affirmativen Grundwertreduziert.

Im zweiten Teil der Arbeit haben wir die Untersuchung auf eine Gruppe von italienischen legasthenen Erwachsenen ausgeweitet. Während Forscher die Verarbeitung von Satznegationen in normal entwickelten Populationen ausgiebig untersucht haben, wurden nur wenige und ziemlich aktuelle Studien zur Verarbeitung von Negationen bei Legasthenikern durchgeführt. Frühere Untersuchungen legen eine erhöhte Schwierigkeit bei der Interpretation negativer Sätze bei Legasthenikern (Vender & Delfitto 2010, Scappini et al. 2015) und schlechten Lesern (Hu et al. 2018) im Vergleich zu normal entwickelten Gleichaltrigen nahe, was vermutlich auf Kapazitätsbeschränkungen des Arbeitsgedächtnisses der Teilnehmer zurückzuführen ist, die sie daran hindern, zu anspruchsvolle linguistische Vorgänge durchzuführen. Nichtsdestotrotz liefern

diese Studien widersprüchliche Hinweise darauf, ob die Satznegation im nichtinkrementellen Rahmen der Negationsverarbeitung bei Legasthenikern konkret zur Quelle der Verarbeitungskomplexität wird, oder ob Legastheniker von einer allgemeineren Reduktion Verarbeitungsfähgkeit betroffen sind.

Es wurde eine Folgestudie mit legasthenen Erwachsenen und normal entwickelten, altersgleichen Personen durchgeführt, um die Beziehung zwischen Legasthenie, der Verarbeitung des negativen Satzes und der Arbeitsgedächtniskapazität zu erforschen. Die Ergebnisse replizieren die Befunde des ersten Experiments: Ähnlich wie normal entwickelte Probanden wenden Legastheniker eine nichtinkrementelle Strategie der Negationsverarbeitung an, und die visuelle Hervorhebung der negierten Information hat einen positiven Effekt auf die Verarbeitung negativer Sätze. Darüber hinaus stellen wir fest, dass Legastheniker im Vergleich zu Kontrollpersonen größere Schwierigkeiten bei der Interpretation sowohl von affirmativen als auch von negativen Sätzen aufweisen, was nicht vollständig auf den höheren Verarbeitungsaufwand der Verneinung zurückzuführen sein kann.

General overview

The aim of the present work is two-fold. First, we aim at contributing to the broad theoretical debate on the processing of sentential negation by providing new relevant insights on how visual and linguistic stimuli interact during the real-time sentence comprehension of negative sentences. Second, we are interested in deepening the relationship between working memory resources, developmental dyslexia and negative sentence interpretation. To this end, we conduct two eye-tracking studies based on a new experimental protocol that combines the strength of more classical sentence-picture verification tasks (traditionally employed in psycholinguistic research) and the visual world experimental set-up, so to exhaustively study how linguistic and visual processes jointly determine the online understanding of negative sentences by these two populations.

This dissertation is set up as follows: in chapter 1, we provide a general overview of the phenomenon of linguistic negation by discussing some of the most relevant (and debated) issues concerning semantic, structural, and acquisitional aspects of sentential negation. This chapter serves as a brief introduction to this topic of linguistic research, and aims to provide the reader with some relevant insights and considerations about its formal and interpretative complexity.

In chapter 2, we discuss the broad theoretical debate about the processing of sentential negation, which constitutes the starting point for this experimental work. We outline those that can be considered as the two main theoretical frameworks of negation processing (i.e., incremental vs. non-incremental models) based on how they account for the two core aspects of the processing that are currently debated: i) the timing and mode of negation integration into sentence meaning; ii) the role of the information occurring under the scope of negation during the sentence interpretation process. Experimental psycholinguistic evidence in support of the different models is also presented and discussed thoroughly.

Chapter 3 introduces the *visual world paradigm* for the study of language comprehension, which employs the recording of participants' eye movements during listening tasks and constitutes the experimental methodology at the base of the present work. First, we outline some of the key features of visual world studies on language processing at both the word and the sentence level. Then, we present in detail two (of the very few) relevant studies conducted using this methodology to investigate negation processing: in doing so, we discuss some of their important limitations concerning the result interpretation and the experimental set-up. Next, we discuss the main advantages and limitations of using the *visual world paradigm* to investigate negation processing compared to the more classical behavioural paradigms (e.g., sentence-picture verification task) described in chapter 2. Finally, we describe the visual manipulation that we decided to introduce in our experimental set-up to overcome some specific limitations which are intrinsically related to the perceptual nature of the *visual world paradigm*, and we outline our research questions.

Chapter 4 is dedicated to the presentation and discussion of our eye-tracking study on the processing of sentential negation in Italian-speaking adults. First, we present the experimental design, the task, as well as the materials and methods. Then, we outline our predictions with respect to our main research questions and the possible expected outcomes. Next, we discuss the results of the eye movement analyses conducted, and we interpret the current findings within the broad theoretical debate on negation processing outlined in chapter 2. As we will see, the results of this first study provide compelling evidence in support of a non-incremental processing of negation, along the lines of the Two-Step Simulation Hypothesis (Kaup et al. 2007); moreover, they reveal a positive effect of the negated information on the negative sentence interpretation process. These main findings pave the way for the last two chapters of the dissertation, in which the investigation of negation processing has been extended to atypical populations, more in particular to individuals diagnosed with developmental dyslexia.

Chapter 5 illustrates the background for our second eye-tracking study with Italian dyslexic adults. First, we offer a brief introduction to developmental dyslexia and to its major linguistic manifestations. Then, we discuss the *Working Memory Deficit Hypothesis* (McLoughlin et al. 1994, 2002) which accounts for the deficits attested in dyslexia by assuming specific limitations in dyslexics' working memory capacity and processing resources: this constitutes the theoretical framework of the experimental study in chapter 6. Subsequently, we review the previous (little) literature dealing with the relationship between developmental dyslexia, working memory resources and sentence processing. Throughout the discussion, we put emphasis on how these previous works have provided conflicting evidence on whether or not negation constitutes a specific source of processing difficulty for dyslexic individuals. We conclude the chapter by outlining our research questions based on our former findings on negation processing reported for normal readers in chapter 4 and on the experimental evidence reviewed in this chapter.

In chapter 6, we present our follow-up study investigating the processing of sentential negation in Italian dyslexic adults. We administered a reduced version of the experimental protocol described in chapter 4 to a group of Italian dyslexic adults and a control group of normal readers. The chapter is organized along the lines of chapter 4. First, we summary the experimental design and the task used. Then we describe the experimental procedure and the materials: a battery of working memory and reading tasks was also included to assess participants' behavioural performance. Next, the results of these behavioural measures and of the eye movement data are presented in detail. The theoretical implications of our findings are then extensively discussed: as we will see, the results of this study show that dyslexics adopt the same non-incremental strategy of negation processing as controls and also benefit from being presented with the negated information during the processing (in line with the results of our former experiment); nonetheless, they display an overall lower-than-normal performance in task execution, suggesting that negation is not specifically impaired in developmental dyslexia, but that dyslexia is characterized by an overall processing impairment. We conclude by discussing some limitations of the present study and providing insights for future research directions.

Finally, chapter 7 contains our final remarks and overall conclusions. We summarize how the present work can contribute to the broad theoretical debate on the processing of sentential negation (chs. 2-4) and to the investigation of the relationship between working memory resources, negative sentence interpretation and developmental dyslexia (chs. 5-6). Some limitations are also discussed.

1 Some notes on linguistic negation

Negation is a universal feature of human language, which is absent from other complex systems of animal communication (Greenberg 1966, Horn 1989). This specific linguistic tool performs several, heterogeneous communicative functions in our daily interactions: from denying a concept to correcting a presupposition; from contradicting an assumption made by another speaker to reject an object or an action; from lying to speaking ironically. What makes negation a very fascinating topic of linguistic research is that, despite its apparent simplicity, the investigation of the forms and meanings of negative expressions is often far from simple and straightforward. Nonetheless, negation constitutes a very complex and multifaceted linguistic phenomenon, which cannot (and is not intended to) be discussed exhaustively in this introductory section.

The aim of this chapter is to provide the reader with a preliminary overview of some interpretative (§1.1), structural (§1.2) and acquisitional aspects (§1.3) of negation, which are of central relevance for the present thesis. First, we will introduce the notion of negation - the core topic of this work: we will describe some of its formal properties as a logical operator and discuss how its interpretation in natural languages is not always that clear-cut as in propositional logic (§1.1.1). This interpretative aspect is related to the fact that the part of the sentence affected by the domain of negation may vary, yielding different semantic interpretations (§1.1.2). The discussion on the scopal domain of negation will lead us to introduce the key concept of sentential negation (§1.1.3), the linguistic structure at the centre of our experimental research. In §1.1.4, we will then address the fundamental asymmetry between affirmative and negative sentences. Besides being more complex from a structural perspective, negative sentences are generally less specific and informative than affirmatives, unless they are used to correct a presupposition and/or expectation established in the discourse context. The relationship between pragmatic contextual factors and the higher processing costs traditionally reported for negative sentences has been largely called into question in the psycholinguistic research on the processing of sentential negation. As we will see in detail in chapter 2, while the different theoretical accounts agree on the fact that the high pragmatic sensitivity of negation plays a role in the processing, they remain instead divided on whether this processing difficulty can be completely attributable to pragmatic factors, or rather it is due to more complex mental representations involved in the computation.

In the second part of the chapter, we will present the different ways in which natural languages can express sentential negation (§1.2.1), as well as the syntactic properties of the different types of negative markers (§1.2.2, §1.2.3). This general overview will pave the way for a more detailed discussion of how sentential negation can be expressed in Standard Italian, the language which constitutes the focus of the present work. In §1.2.4, we will provide the reader with relevant insights concerning the different syntactic structures that a *non-strict Negative Concord language* such as Italian has at its disposal to convey the sentence negative meaning.

The third and last section of the chapter deals with the emergence of (sentential) negation in Child language. We will see that children need time to acquire the different semantic meanings of negation (i.e., *rejection, non-existence and truth-functional negation*, §1.3.1), the syntactic forms employed to express sentential negation (§1.3.2), and the correct distribution of the negative markers (§1.3.3). In section 1.3.1, we will underline how the emergence of the different semantic meanings that sentential negation can convey is gradual and arguably related to the development of the child's computational abilities, as they involve different levels of cognitive complexity and abstract representations. This aspect of the processing will be subsequently addressed in the discussion of our experimental findings, as it leads to interesting predictions concerning the interplay between vision and language in the construction of the sentence negative meaning.

1.1 The semantics of negation

In logical terms, negation is an operator that takes a proposition p to another proposition $\neg p$ by reversing its truth-values: that is, if p is a formula, then $\neg p$ is false if p is true, and $\neg p$ is true if p is false. From a semantic perspective, negation can therefore be considered as a phenomenon of opposition. Nevertheless, despite its alleged simplicity, the interpretation of negation in natural languages is not so straightforward as in propositional logic. In the following sections, we will outline some of the central issues concerning the semantics of negation that have been exstensively studied (and debated) throughout the centuries.

In section §1.1.1., we will have a look at some formal properties of negation that can be traced back to classical logic: in doing so, we will discuss the distinction made by Aristotle between different types of negation (i.e., contrariety and contradiction) corresponding to different kinds of semantic opposition. Then, in §1.1.2, we will address the broad debate on the truth-value assignment to negative sentences referring to non-existing entities. This will allow us to introduce two key concepts: the notion of *existential presupposition*, and the distinction between *narrow* and *wide scope* of negation. As we will see in §1.1.3, Klima's (1964) influential definition of sentential and constituent negation is based upon this latter difference in the scope domain of the negative operator, which may yield different semantic interpretations of the negative sentence. Finally, in §1.1.4, we will discuss the asymmetry between negative and affirmative propositions that characterizes natural languages. Besides being more complex than their affirmative counterparts in morpho-syntactic terms, we will see that negative sentences can be considered more marked also from both a semantic and pragmatic perspective, as they are prototypically used to correct a presupposition and/or assertion established in the discourse context.

1.1.1 Negation in classical logic

In Aristotelian logic, negation is governed by two different laws: the Law of Contradiction (LC), and the Law of the Excluded Middle (LEM). The former states that two opposite propositions cannot be true simultaneously (1), whereas the latter demands that one of the two opposite propositions is true (2).

(1) Law of Contradiction: $\neg (p \land \neg p)$
(2) Law of the Excluded Middle: $\neg p \lor p$

As exemplified in (3), standard negation obeys both these logical rules. It is in fact immediately clear that these sentences cannot both be true (LC), as it is not possible for number 4 to be simultaneously an even and an odd (i.e., not even) number; at the same time, one of the two sentences in (3) has to be necessarily true (LEM): whatever type of number 4 may be, it is either an even or an odd number.

(3) a. 4 is an even number
b. 4 is not an even number

However, there are many instances of negation in which the Law of Excluded Middle does not hold. Consider for example the following sentences:

(4) a. John is friendly
b. John is unfriendly

While these two opposite sentences cannot be simultaneously true in the same situation, as stated by the Law of Contradiction, it might be the case however that none of them is actually true: indeed, John can be neither friendly nor unfriendly, but rather something *in between*. Horn (1989) defined these types of predicates as *scalar predicates*: as the name suggests, they denote a scale in which the two terms at the extremities (e.g., friendly and unfriendly) are not immediate contraries as in the case of even vs. odd, but they allow other elements to mediate between them, creating a scale of possible contraries.

This observation underpins the distinction made by Aristotle between two different kinds of negation, on the basis of whether the two fundamental logical laws are respected. Sentence (3b) constitutes an example of *contradictory negation*, in which both LC and LEM apply: two contradictories, such as *even* and *odd* cannot be both false at the same time for the same object, but one member of the pair must be true and the other false. In addition, no intermediate elements are allowed between the two opposite terms. Conversely, *contrary negation* only obeys LC:

while it is impossible for one property to be simultaneously asserted and negated for the same entity, it may in fact be the case that something exists between contraries. Consider, for instance, two contrary terms such as *friendly* and *unfriendly*: a person cannot be both friendly and unfriendly at the same time, but she can certainly be neither, being merely affable.

In conclusion, Aristotelian logic of opposition distinguishes the notion of contrariety from the notion of contradiction on the basis of two fundamental principles: the Law of Contradiction, which holds for both types of negation, and the Law of the Excluded Middle, which does not hold in the case of the so-called scalar predicates. Nevertheless, these logical laws are considered valid, and therefore applicable, only in if the propositional subject corresponds to an existing entity. Consider, for instance, the sentences in (5), where the subject of predication (i.e., Santa Claus) denotes a non-existing entity.

(5) a. Santa Claus is ill
b. Santa Claus is well
c. Santa Claus is not ill

If Santa Claus exists, one of the two affirmative sentences in (5a) and (5b) will be true and the other false: instead, if Socrates does not exist, both will turn out to be false. For what concerns the negative proposition in (5c), it will be either true or false if Santa Claus exists, but, crucially, it will be true in the case that Santa Claus does not exist. Aristotle argues in fact that denying the predication of a non-existing entity results in a logically true statement. A predicate denial of the form *p is not q* is true if and only if the corresponding affirmative proposition *p is q* is false. If Santa Claus does not exist, it is false to say that Santa Claus is ill (5a): hence, that the negative sentence *Santa Claus is not ill* (5c) must be true.

1.1.2 Negation and truth-value assignment

So far, we have seen that denying the predicate of non-existing entities returns a true value in Aristotelian logic. Given this counterintuitive conclusion, the issue of truth-value assignment to the predication of vacant objects has been widely debated over the centuries from both a philosophical and a linguistic perspective.

Frege (1982) introduced the notion of *existential presupposition*, which constitutes a necessary assumption required to understand the meaning of a sentence but it is not included in its logical form. In particular, he argues that both affirmative and negative sentences including proper names or definite descriptions as propositional subjects presuppose the existence of a referent for that entity in the real world. Consider, for instance, the pair of sentences in (6): in Frege’s words, if one asserts (6a) or (6b), there is a presupposition that the name “Kepler” designates something, that is, that Kepler existed (Frege 1952:69).

(6) a. Kepler died in misery
b. Kepler did not die in misery

In the case of non-existing entities, this presupposition does not emerge as the subject has no proper reference nor extension in the real world. Frege concludes that these sentences cannot be assigned with a truth-value and cannot therefore be used to make an assertion. This approach was largely criticized by Russell (1905), who argued that sentences like (7) could still be assigned with a truth-value although they lack proper reference.

(7) The king of France is bald

This affirmative sentence assumes that there is a unique entity which is the King of France and he is bald, as expressed through the following logical form:

(8) $\exists x\ (KING(x) \land \neg\exists y\ (x \neq y \land KING(y)) \land BALD(x))$

In this framework, sentence (7) is conceived as false because there is not such an entity with the property of being the King of France and of being bald. Instead, Russell proposed that the corresponding negative sentence (9) is ambiguous between two possible readings depending on the scope of the negative operator *not*: either the negation could be interpreted as sentence-wide (i.e., external negation), or as local to the verb (i.e., internal negation). Significantly, these two different readings of negation correspond to different logical forms with different truth-values, giving rise to two possible interpretations for the one sentence in (9).

(9) The king of France is not bald

(10) External negation (wide-scope) $\neg\ \exists x\ (KING(x) \land \neg\exists y\ (x \neq y \land KING(y)) \land BALD(x))$

External reading: It is not the case that both (a) there is a unique King of France and (b) he is bald

(11) Internal negation (narrow-scope) $\exists x\ (KING(x) \land \neg\exists y\ (x \neq y \land KING(y)) \land \neg\ BALD(x))$

Internal reading: There is a unique King of France and he is not bald

In (10), negation is external having scope over the entire proposition: the sentence denies the existence of a univocal entity who is the King of France and who is bald. However, the first of the two conjuncts is false, as we know that there is no entity which satisfies the property of being the King of France: hence, the proposition in (9) is true. As Russell observed, this possible interpretation of the negative sentence in (9) is made more evident if we consider the following example:

(12) The King of France is not bald – because there is no such person.

This sentence, which is indeed perfectly acceptable, is only compatible with a wide-scope reading of negation, as it makes clear that the falsity of the proposition can be determined by the fact that there is no actual referent for the definite description "the King of France". Conversely, in (11) the definite description does not fall within the scope of negation, which is hence defined as internal. The narrow scope of negation leads to the following interpretation of sentence (9): there is a unique King of France, and this entity is not bald. Crucially, this possible reading of the negative sentence shares the same existential presupposition reported for its affirmative counterpart (7), that is, the existence of an entity which is the King of France: given that there is not such a referent in the real world, the negative sentence must be judged as false.

Russell's approach was however not free from criticism. His proposal of considering the interpretation of negative sentences as ambiguous depending on the scope of the negative operator has been in fact largely criticized by Strawson (1950, 1964): along the lines of Frege's account, he argues that any statement with a non-denoting subject cannot be assigned with a truth-conditional meaning, given that the existential presupposition is not satisfied. The debate on truth-value assignment for sentences with non-denoting entities is complex and touches upon several issues.[1] For the aim of this general overview, we are mainly interested in underlining how the distinction between narrow and wide scope of negation is at the basis of Klima's (1964) definition of sentential and constituent negation, which we will briefly illustrate in the following section.

1.1.3 The scope of negation

As an operator, negation has scope over the surrounding elements: however, the part of the sentence which is affected by the domain of negation may vary, leading to different semantic interpretations. Klima (1964) has drawn an important distinction between sentential and constituent negation[2]: while the former affects the meaning of the clause, the latter only applies to a specific subcomponent of the sentence itself. Consider, for instance, the following example:

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[1] The interested reader is referred to Horn (1989) and Vender (2017) for an exhaustive discussion of the topic.

[2] Klima (1964) developed a series of tests to distinguish between sentential and constituent negation: for instance, sentences involving the former can be followed by positive question tags or *either* phrases, whereas sentences involving the latter can be followed by negative question tags or *too* phrases. Although these tests met with criticism, this was concerned with the criteria employed for the diagnostics and not with the distinction between the two different types of negation (see Zeijlstra 2004 for a more detailed discussion of the diagnostics and related issues).

(13) a. With no job is Kim happy
b. With no job Kim is happy

Both sentences include the same negative constituent. Nonetheless, only in (13a) the sentence conveys a negative meaning, as it denies Kim's happiness. Quite the opposite, (13b) describes under which circumstances Kim is indeed happy, and negation affects only the PP *with no job*. Therefore, sentence (13a) exhibits sentential negation, whereas sentence (13b) constituent negation.[3]

So far, we have seen that the presence of a negative operator, having scope either on the entire proposition or only on a particular constituent, modifies the truth values of the sentence. However, Horn (1985, 1989) observed that there are cases in which negation is not used to deny an utterance's propositional content but, rather, it serves as a metalinguistic device for objecting to the way in which a propositional meaning had been previously expressed. This linguistic phenomenon, labelled as *metalinguistic negation*, is an instance of non-standard negation scope, as it involves objections to the non-truth conditional contents of the utterance.

(14) I haven't stopped smoking; I have never smoked in my life[4]
(15) Goliath wasn't tall; he was giant
(16) Joe doesn't [mijənidʒ] singers; he [mænədʒəz] them

As can be observed in (14-16), metalinguistic negation can target presuppositions, such as that the speaker in (14) used to smoke (Burton-Roberts 1989), conversational implicatures, such as the scalar implicature associated with the term *tall* in (15), and even the way in which a part of the utterance was pronounced (16). Note that the objection expressed by negation is typically followed by a rectification, which, significantly, is truth-conditionally equivalent to the formerly negated proposition.

To conclude, another instance of pragmatic use of negation is the so-called *illocutionary negation* (Searle 1969, 1972; Moeschler 1992, 2010), in which the wide scope of negation affects the realisation of the speech act itself rather than the propositional content of the sentence itself. Consider, for instance, the following sentences:

[3] The example reported in (13) indicates that constituent and sentential negation are not mutually exclusive: rather, (13a) can be considered as an instance of constituent negation that is also able to express sentential negation. This suggests that sentential negation should be defined in semantic terms, as proposed by Acquaviva (1997) along the lines of Jackendoff (1969, 1972). The interested reader is referred to Zeijlstra (2004, 2013) for a detailed discussion on the semantic and syntactic approaches to the analysis of sentential negation.

[4] Examples taken from Horn (1985:132)

(17) I don't promise I will speak ill of my colleagues[5]
(18) I promise you I won't speak ill of my colleagues

In the former, negation scopes over the illocutionary force associated with the predicate *to promise* (F), signalling a refusal of commitment to the speech act by the speaker (19). Conversely, in the latter, negation does not scope over the illocutionary marker of the sentence but over the propositional meaning of the subordinate clause (P) – as exemplified in (20).

(19) not-promise (I will speak ill of my colleagues): $\neg$ F (P)
(20) promise (not (I will speak ill of my colleagues)): F ($\neg$P)

1.1.4 Markedness of negation

Natural languages are characterized by an asymmetry between affirmative and negative sentences, with the latter being always marked in comparison to their affirmative counterpart in both language structure and use (Dahl 1979, Payne 1985, Horn 1989, Ladusaw 1996).

As noted by Greenberg (1966), negative sentences are always expressed by means of an overt linguistic element. Significantly, this formal markedness is specific of negation: in fact, although natural languages display a lot of cross-linguistic variation with respect to the morphosyntactic elements used for expressing sentential negation (§1.2.1), negative sentences are structurally more complex than the corresponding affirmative ones. Indeed, any statement is automatically interpreted as an affirmation unless its negative meaning is made explicit by one (or more) specific linguistic element.

Besides being morpho-syntactically more marked, negative statements are also generally less informative than affirmatives. Consider, for instance, the following sentences:

(21) Abraham Lincoln was not shot by Ivan Mazeppa[6]
(22) Abraham Lincoln was shot by John Wilkes Booth

Both these statements are equally true, but the reader can immediately perceive how the negative sentence (21) is much less informative than the affirmative one (22): while the latter provides in fact precise information about who shot the President, the former does not exclude any but one of the billions of people who might have shot him. This intuition has been formalized in the *Principle of Negative Uninformativeness* by Leech (1981), who argued that negative sentences are more informative than the corresponding affirmatives only when uttered in specific

[5] Examples taken from Moeschler (1992:52)
[6] Examples taken from Leech (1981)

discourse contexts[7]. The negative sentence in (21) is perceived by the speaker as inappropriate when uttered out of the blue, as it violates the Gricean Maxim of Relevance (1975) which requires the speaker to be as informative as possible: in fact, the number of people who did not shoot Abraham Lincoln is way greater than the number of people who actually shot him. Nevertheless, the very same negative sentence becomes perfectly acceptable in a context in which the speaker has a specific communicative intent, as in the following example:

(23) Speaker A: Abraham Lincoln was shot by Ivan Mazeppa
Speaker B: No, you are wrong. Abraham Lincoln was not shot by Ivan Mazeppa. He was shot by John Wilkes Booth!

Here, (23) is very informative as it is used to deny a statement which has been previously introduced by someone in the discourse context, that is, the assumption that Ivan Mazeppa was involved in the assassination of Lincoln.

Leech's (1981) intuition about the informativeness of negative sentences uttered in inappropriate discourse contexts underpins the concept of *markedness implicature* subsequently formulated by Horn (1989): while speakers use affirmative statements to simply convey a piece of information, negative sentences are uttered with the aim of expressing an additional communicative effect. A similar observation was made by Wason (1965), who introduced the notion of *plausible denial*: according to the author, negative sentences are used to correct an asserted presupposition or a previous expectation which has been established in the communicative context. On the contrary, the decontextualized occurrence of negative sentences conveys a sense of inappropriateness, and their interpretation would be burdened by the need for the addressee to accommodate lack of contextual information. The relationship between pragmatic contextual factors and the higher processing costs that seem to be associated with negative sentences has been extensively investigated in the psycholinguistic literature on the processing of sentential negation, and will be discussed in detail in chapter 2.

1.2 The syntax of negation

In all world languages, the expression of sentential negation always requires the presence of an overt linguistic element (segmental or suprasegmental, such in the

[7] It is worth noting that negative sentences are as informative as their positive counterparts only in the case of contradictory predicates (e.g., *open/close, on/off*), which cannot receive a scalar interpretation (Horn 1989, see §1.1). However, the resort to a negative form (e.g., *the radio is not on*) still seems to be related to the expression of some additional communicative effect compared to the affirmative form conveying the same information (e.g., *the radio is off*). Furthermore, contrary negation ones may even be more informative (e.g., *John is 1.50m short* may be more informative than *John is 1.50m tall*)

case of tone). However, substantial cross-linguistic variation is attested in respect to how the negative meaning may be conveyed. In section §1.2.1, we will provide the reader with an overview of the three main classes of negative elements used to express sentential negation across languages: throughout the discussion, we will see that the range of variation concerns the type, the number, and also the position of these negative elements. The following sections are devoted to a brief discussion regarding the underlying syntax of the different types of negative markers: in particular, we will cover some central issues addressed by scholars over the past decades concerning the syntactic status of these negative elements (§1.2.2) as well as their position within the clausal structure (§1.2.3). To conclude, in section §1.2.4, we will outline the various syntactic constructions allowed in Standard Italian to express sentential negation: in doing so, we will illustrate the linguistic phenomenon known as *negative concord* providing some theoretical insights.

1.2.1 The expression of sentential negation

In §1.1.4, we have seen that the expression of a negative sentence is always marked in comparison to its affirmative counterpart by the presence of an overt linguistic element. In fact, differently from other grammatical functions (e.g., interrogative constructions), there is no language in which sentential negation can be expressed merely by means of a word order shift (Horn 1989, Zeijlstra 2009). Nonetheless, natural languages display a lot of cross-linguistic variation in the possible ways of expressing sentential negation, with regard to the type, position and number of the negative markers employed.

Zanuttini (2001) distinguished four main types of negative elements used to express sentential negation. First, some languages make use of special verbs to deny a sentence: it is the case of many Polynesian languages, in which negative verbs have scope over the entire clause. Instead, in languages such as Evenki (spoken in Siberia), the sentence negative meaning can be conveyed by means of a negative marker which has the properties of a finite auxiliary. A third type of negative markers are those anchored in the inflectional morphology of the verbs. For instance, the Turkish language (24) expresses sentential negation by means of a negative morpheme placed between the verbal stem and the temporal and personal inflectional affixes.

(24) John elmalari ser*me*di[8]
John apples like.neg.past.3sg
'John doesn't like apples

The last class of strategies is represented by the use of negative particles to express

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[8] Example taken from Ouhalla (1991), also cited in Zanuttini (2001) and Zeijlstra (2013)

sentential negation. Within this latter group, Zanuttini (1997, 2001) and Zeijlstra (2007) made a further distinction between two main types of negative particles, depending on whether these markers must be attached to the finite verb or not. In languages such as Italian (25) and Czech (26), the negative particle occupies a fixed position to the immediate left of the finite verb. However, this class of *preverbal negative markers* (Zanuttini 1997, among others[9]) displays some degree of internal variations: while in Italian the negative marker *non* constitutes a free-standing morphological word, in Czech the element *ne* is instead anchored to the finite verb.

(25) Gianni *non* ha telefonato
Gianni neg has called
'Gianni didn't call'

(26) Milan *ne*vola´
Milan neg.calls
'Milan doesn't call'

Languages such as German (27) are instead characterized by the fact that the position of the negative particle does not depend on the surface syntactic position of the finite verb. In V2 languages, the finite verb necessarily occupies the second position in the main clause: in a negative sentence like (27a), the verb has therefore to move over the negative element to reach this second position, but such movement does not trigger the displacement of the negative adverb *nicht*.

(27) a. Hans kommt nicht[10]
Hans comes neg
'Hans doesn't come'
b. ..., dass Hans nicht kommt
... that Hans neg comes
'... that Hans doesn't come'

In the following section, we will see how the different distributional properties exhibited by these two types of negative particles can be traced back to a distinction in their syntactic status.

1.2.2 The syntactic status of negative markers

In her influential works on negation in Romance varieties, Zanuttini (1997, 2001) developed a series of tests with the aim of determining the syntactic status of negative elements. Significantly, the analyses provided compelling evidence that

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[9] The reader is referred to Zanuttini (1997) and Poletto (2008) for a comprehensive overview of different types of preverbal negative markers in Romance varieties

[10] Example taken from Zeijlstra (2013:797)

the preverbal negative markers are syntactic heads having the entire VP as complement. The first observation concerns the syntactic phenomenon known as *clitic climbing*, in which a pronominal object of an embedded infinitive is moved out of its local domain and cliticized on the matrix verb (Kayne 1989, Rizzi 1982), as exemplified below:

(28) a. Gianni vuole vederli
Gianni wants see-them
b. Gianni li vuole vedere
Gianni them wants see
'Gianni wants to see them'

As can be observed in the French example (29), such movement is blocked in presence of a negative marker, requiring the object clitic to remain in its canonical position. Zanuttini (2001) argued that this blocking effect must be due to the negative marker *ne* being an intervening head which prevents the antecedent government of the trace, also considering that the clitic movement over the negative particle *pas* (29c) is instead perfectly allowed.

(29) a. Jean la_1 fait manger t_1 a` Paul[11]
Jean it makes eat to Paul
'Jean makes Paul eat it'
b. *Jean l_1'a fait ne pas manger t_1 a` l'enfant
Jean it.has made neg neg eat to the child
'Jean has made the child not eat it'
c. Jean ne l_1'a pas fait manger t_1 a` Paul
Jean neg it.has neg made eat to Paul
'Jean hasn't made Paul eat it'

Additional evidence in favour of the head status of preverbal negative markers comes from the blocking of verb movement attested in Paduan (Poletto 2000, Zanuttini 2007). In this Northern Italian dialect, yes/no interrogative clauses requires the C^0 to be overtly filled. As a consequence, in interrogatives such (30), the main verb moves from V^0 to C^0. However, the Head Movement Constraint (Travis 1984) prohibits this V-to-C movement in the presence of an overtly filled intervening head. Significantly, this is exactly what Zanuttini (2007) found for negative interrogatives (31), confirming that the Paduan negative marker *no* is an intervening head which blocks the syntactic verb movement.

(30) Vien-lo?
comes-he

[11] Examples taken from Zanuttini (2001) also cited in Zeijlstra (2013:799)

'Is he coming?'

(31) *Vien-lo no?
comes-he neg?
'Isn't he coming?'

Further confirmation of the syntactic head status of the preverbal negative particles has been provided by Merchant (2006), who developed the so-called *why not* test. Given that the *why not* construction is considered as a form of phrasal adjunction, Merchant (2006) predicted that such construction should not be allowed in those languages in which the negative markers are syntactic heads instead of phrasal elements. This is precisely what happens in many languages with preverbal negative markers, including Italian (32), where the negative particle *non* cannot participate in the *why not* construction and the word *no* must be used in its place.

(32) *Perché non?
why neg
'Why not?'

Zeijlstra (2004, 2013) made use of the same diagnostics to investigate the syntactic status of those negative particles whose position remains unaffected from the surface position of the finite verb. Zeijlstra started out with the assumption that if preverbal negative markers are functional heads, these other negative particles must occupy a different position in the clausal spine, and should hence be considered as phrasal elements (i.e., XPs).

Empirical evidence from verb movement analyses in V2 languages provides first support to this assumption. As exemplified above for German (27), the negative marker *nicht* does not block V-to-C movement of the finite verb over the negative element to C^0 in the main clause, confirming that negative adverbs are not syntactic heads. Evidence that negative adverbs behave as maximal projections is also provided by the application of the *why not* test. As shown below, these negative elements are in fact allowed to adjoin to *why* in the *why not* construction, which, as said, is a form of phrasal adjunction.

(33) a. Why not? (English)
b. Warum nicht? (German)
c. Waarom niet? (Dutch)
why neg
'Why not?'

Summarizing, in this section we have seen that the difference between the two types of negative particles used to express sentential negation can be reduced to a formal syntactic distinction: preverbal negative markers that attach to a finite verb (e.g., the Italian *non*) occupy a head position in a specific functional projection; the negative adverbs, whose syntactic position remains unaffected by the surface position of the finite verb (e.g., *nicht* in German) behave instead as phrasal elements.

1.2.3 The syntactic position of negative markers

As said, negative markers can be syntactic heads of a functional projection, labelled as Negation Phrase (NegP). This observation paved the way for an extensive discussion among scholars on what exact position this NegP occupies within the clause (Pollock 1989, 1993; Belletti 1990, Laka 1990, Zanuttini 1991, Haegeman 1995, Ouhalla 2003; Zeijlstra 2004, 2006). Far from receiving general consensus, in this section we will briefly outline the main proposals put forward in this respect[12].

While Pollock (1989) maintained that the negative projection is located below TP and above AgrP, subsequent works did not assume that NegP occupies a fixed and universally pre-determined position. For instance, Ouhalla (2003) argued that the syntactic position of NegP in the clause is the result of a parametric variation, which causes NegP to select either TP or VP. In addition, the different values assigned by this NEG parameter would account for the cross-linguistic variation attested between Romance and Germanic languages in the ways of expressing sentential negation, with NegP dominating TP only in the former. Based on data from different Italian dialects, Zanuttini (1991, 1997) further developed the idea of a more flexible position occupied by NegP. In fact, she hypothesized the presence of four Negative Phrases within the clausal structure, which are universally available and could potentially all host a different negative marker. According to Zanuttini, the different types of negative markers in Romance varieties which exhibit different syntactic and/or semantic properties would hence occupy a different position in the syntactic structure.[13] However, as pointed out by Zeijlstra (2004), the observation that negative markers have a broad distribution within the clause does not necessarily imply the existence of a more articulated and fixed syntactic structure that holds universally for all languages: rather, it might simply indicate a relatively free syntactic distribution of the negative markers.

This intuition has been extensively developed by Zeijlstra (2004, 2013) who proposed a semantic derivation of the NegP position in the clause, following Nilsen's (2003) idea that functional categories are not syntactically but rather semantically driven. Two important observations have been put forward by the author. First, in order to express sentential negation, a negative marker must necessarily have scope over the entire vP (Zeijlstra 2004): this would be sufficient

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[12] The interested reader is referred to the overview proposed in Zeijlstra (2004) for a detailed evaluation and discussion of the different proposals.

[13] See also Poletto (2000,2008), Benincà (2006), and Manzini and Savoia (2005)

to account for the attested cross-linguistic variation regarding the position of NegP within the clausal structure. Second, negation can never be interpreted in a position at least as high as C^0, otherwise it would outscope those operators with the illocutionary force of a speech act (Zeijlstra 2013, following Han 2011). From these assumptions, it follows that negative markers must occupy an intermediate position within the syntactic structure, which however, is not postulated by any specific syntactic principle. Therefore, Zeijlstra (2004, 2013) considered the syntactic position of the negative marker to be relatively free, arguing that different semantic effects are nevertheless expected depending on the position occupied by the negative marker itself.

A detailed discussion of Zeijlstra's (2004, 2013) approach and of its subsequent implementations (Penka 2007, Cirillo 2009, Breithbarth 2009 among others) goes beyond the aim of the present work, and the interested reader may refer to the original works and to Zeijlstra (2013). To conclude, we want instead to underline how Zeijlstra (2004, 2013)'s assumption of a semantic derivation of the NegP position has the undoubted advantage of accounting for the variety of the possible syntactic positions that can be occupied by negative markers within the clausal structure, without the need to assume a more fine-grained syntactic structure with multiple fixed positions for NegP (cf. Zanuttini 1991, 1997)

1.2.4 Sentential negation in Standard Italian

As the present experimental work will deal with the processing of sentential negation by Italian-speaking adults, this last section aims to provide the reader with a comprehensive overview of the different syntactic constructions used in Italian to express sentential negation. In §1.2.1, we have seen that the Italian language makes use of the preverbal negative marker *non* to introduce the semantic negation, as reported for ease of reading below:

(34) Gianni non ha telefonato
Gianni NEG has called
'Gianni didn't call'

In (35), the semantic negative meaning is conveyed by the single neg-word[14] *nessuno* placed in pre-verbal position, that behaves as a negative quantifier (e.g. the English *nobody*):

(35) Nessuno ha telefonato
n-body has called
'nobody called

[14] In Laka (1990)'s terminology for negative indefinites in NC languages

However, the combination of these two types of negative elements within the same sentence may yield different semantic interpretations. As shown in (36), when the negative marker *non* comes with a negative quantifier placed in post-verbal position, the sentence expresses one single semantic negation.

(36) Gianni *(non) ha telefonato a nessuno
Gianni NEG has called to n-body
'Gianni didn't call anybody'

From a formal logic perspective, the sentence in (36) would be expected to convey a positive meaning: in fact, along the lines of the *Law of Double Negation*, when a proposition includes two negations, they cancel each other out consequently yielding an affirmation. Furthermore, the single negative meaning of sentence (36) seems also to violate the *Principle of Semantic Compositionality*, stating that the meaning of a complex expression is determined by the combination of the meanings of its constituent expressions (Frege 1884).

Sentence (36) is an instance of the linguistic phenomenon known as *negative concord* (Labov 1972): two or more negative elements that are able to individually express negation yield instead a single negative meaning when combined. Negative concord (NC) is a well-attested phenomenon in a large number of Indo-European languages, in both Romance and (some) Germanic varieties[15] as well as in Greek and Albanian (Giannakidou 1997, 2000; Zeijlstra 2004). Giannakidou (1997, 2000) distinguished between two types of languages exhibiting NC constructions: in the so-called *strict NC languages* (e.g., Czech), the negative marker must necessarily be combined with the neg-word/s independently of their position within the sentence; instead, in *non-strict NC languages*, a NC reading can only be established between a negative element in preverbal position (either a neg-word or a negative marker) and neg-words in post-verbal position. Italian belongs to this latter subgroup of NC languages, since, as exemplified in (35), no negative doubling construction is required when the neg-word is in subject position.

Note, however, that NC languages do also license a double negation reading of multiple negative constructions in which, along the lines of propositional logic, the two negative elements cancel each other out. According to Zeijlstra (2004), the NC construction is subject to syntactic locality constraints: in order to provide a single semantic negative reading, all the negative elements must share the same scope domain – that is, they all must be located within the same sentence. Instead, when the relationship is established between negative elements belonging to different

[15] Among Germanic languages, NC is attested for instance in Afrikaans, West Flemish, Yiddish, some Dutch and German dialects like Bavarian

clauses, e.g., the main clause and the subordinate one, the interpretation is of double negation (as long as the embedded clause is in indicative mood):

(37) Non ho detto che nessuno è arrivato[16]
NEG say.1SG that n-body has.IND arrived
DN reading : 'I don't say that nobody has arrived'
*NC reading: 'I don't say that anybody has arrived'

Furthermore, a particular double negation reading can arise in the subgroup of *non-strict NC languages*. The Italian example in (35), repeated here in (38), showed that no negative marker is required to express sentential negation when the neg-word is in preverbal position.

(38) Nessuno ha telefonato
'Nobody has called'

However, when the neg-word in preverbal position is combined with a negative marker, the NC reading is compromised, and a double negation reading can be accessed, *modulo* specific prosodic features.[17] As shown in (39), the negative indefinite *nessuno* and the negative marker *non* cancel each other out yielding an affirmation.

(39) Nessuno non ha telefonato
N-body NEG has called
DN reading: 'Nobody didn't call'
*NC reading: 'Nobody called'

Note that this double negation construction is a marked option, as its use in everyday communication is subject to strict pragmatic restrictions. In particular, this construction is accepted by the speaker only in specific communicative contexts, such as, for example, in order to deny a previous negative assertion made by another speaker or a presupposition established in the context:

(40) Speaker A: 'Né Anna né Maria si sono ricordate del tuo compleanno… Nessuno ha telefonato'
NEG.COP Anna NEG.COP Maria REFL.3PL are remembered of your birthday… N-body has called
'Neither Anna nor Maria remembered your birthday… Nobody called you'

[16] Example taken from Zeijlstra (2004:266)
[17] The neg-word in subject position must be the word on which the primary stress of the sentence is located.

Speaker B: Ma non è vero! Anna ha chiamato la mattina e Maria a mezzogiorno… NESSUNO[18] non ha telefonato!'
But NEG be.COP.PRS.3SG true! Anna has called the morning and Maria at noon… N-body NEG has called!
'But it is not true! Anna called me in the morning and Maria at noon. Nobody didn't call!'

In this respect, the reader will have noticed a clear resemblance to what discussed in §1.1.4 regarding the uninformativeness of negative sentences uttered in unsupportive pragmatic contexts.

Among scholars, different proposals[19] have been made to explain the semantic phenomenon underlying *negative concord*: that is, how it is possible that two elements which are able to express a semantic negative meaning when taken individually, convey instead one single negation when combined within a sentence. A first theoretical account, which considers every negative element to be semantically negative, argued that the interpretation of several negative expressions as a single negation would be the result of a semantic absorption mechanism known as *quantifier resumption* (Zanuttini 1991, Haegeman 1995, Haegeman & Zanuttini 1991, 1996, de Swart & Sag 2002). While this approach may overcome the problem of semantic compositionality, it provides instead no explanation for the reported cross-linguistic variation in exhibiting NC structures. Based on the strong similarities between NPIs and neg-words[20], an opposite approach deemed the latter to be semantically non-negative in nature. However, within this framework, it is unclear how the negative reading of a sentence including a single neg-word (e.g., *Nessuno ha telefonato*) can be derived if this element does not give rise to semantic negation. Zeijlstra (2004, 2008) provided another possible interpretation of *negative concord*, arguing that this phenomenon is a form of syntactic agreement. Following Ladusaw (1992), Zeijlstra takes neg-words to be semantically non-negative indefinites carrying an uninterpretable negative feature [uNeg] that agrees with a semantic negation: when only the neg-word occurs in the sentence, the semantic negation remains phonologically unrealised.

To conclude, we provide an example of how the negative reading of the following Italian sentences can be derived by the syntactic operation of

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[18] Uppercase indicates the primary stress position.
[19] See Zeijlstra (2007, 2008) for a detailed discussion of the existing theoretical accounts.
[20] Three main similarities can be observed between NPIs and neg-words: i) they are interpreted as negative indefinites; ii) they must be licensed by negation; iii) both appear in Downward Entailing (DE) (but not anti-additive) constructions (see Zeijlstra 2013 and Herburger 2001 for a detailed discussion).

Agreement.[21] According to Zeijlstra (2004, 2008), in *non-strict NC languages* such as Italian, the negative marker carries an interpretable negative feature, [iNeg], which is the realisation of the negative operator Op¬.

(41) Gianni non ha telefonato a nessuno
'Gianni didn't call anybody'
[Gianni [NegP [Neg^0 *non*$_{[iNEG]}$] [vP ha telefonato a *nessuno*~~$_{[uNEG]}$~~]]]][22]

The NC construction in (41) is well formed because the indefinite *nessuno*, carrying an [uNeg] feature, establishes a feature checking relation with the negative marker *non*, carrying instead an [iNeg] feature. Instead, in (42), the indefinite *nessuno* in subject position is licensed by an abstract negative operator, Op¬ carrying [iNeg].

(42) Nessuno ha telefonato
'Nobody called'
[NegP [*Op¬* $_{[iNEG]}$-*Nessuno*$_{[uNEG]i}$] [vP t_i ha telefonato]]

Summarizing, Zeijlstra (2004, 2008) maintained that, in *non-strict NC languages*, sentential negation is the result of the syntactic operation of Agreement between the negative expressions carrying a [uNeg] feature and the negative operator carrying an [iNeg] feature, which can be either overtly (41) or covertly (42) realised.

1.3 Negation in early language acquisition

Although negation in natural languages is a complex and heterogeneous phenomenon, the earliest instances of linguistic negation appear in children's repertoire by 18 and 24 months of life. Nevertheless, its acquisition and development is gradual: it takes time for children to understand the semantic meanings of the different negative words to be able to use them correctly into fully developed sentences. Moreover, in order to understand how to negate a sentence, children must also learn how negation can have scope over the different part of the sentences, leaving the others unaffected. These acquisitional aspects will be briefly discussed in the following sections, in which we will describe three major insights of the cross-linguistic literature on the early acquisition of negation[23]. In section §1.3.1, we will discuss the categorization of the different semantic meanings of

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[21] The interested reader is referred to Zeijlstra (2004) for a comprehensive evaluation of the syntactic feature checking relations underlying the different instances of sentential negation in NC and DC languages.
[22] Examples (41) and (42) are adapted from Zeijlstra (2004).
[23] Acquisitional studies on negation in child language involving Italian as target L1 language are quite lacking. Volterra and Antinucci (1979)'s pragmatic study on the emergence of negative meanings is the principal work on the acquisition of negation in L1 Italian: however, it has been widely criticized in subsequent literature (among others, Pea 1980).

negation, as well as two influential proposals for a developmental sequence of their emergence during the single-word utterance period and in the multiword speech productions. Section §1.3.2 is dedicated to the acquisition of the different forms of negation in child negative sentences: we will outline the main differences between anaphoric and sentential negation, including their position in the sentence and their different scope domain over the sentence itself. Finally, in section §1.3.3, we will see how children acquire the distribution of sentential negation through different developmental stages in which the negative marker moves from a sentence external to a sentence internal position.

1.3.1 Emergence of meanings of negation

As soon as they begin to speak (at about one year of age), children start using negative words apparently without significant problems. Nonetheless, these earliest negation forms do not cover the entire range of negative meanings used in adult languages, as the lexical differentiation of negative words and their inclusion into fully developed utterances require time and increasingly mental resources.

At the beginning of its development in language use, negation has essentially affective and volitional functions: that is, children use it to express their emotions and intentions about a state of affairs in the extra-linguistic context. On the contrary, children seem to acquire truth-functional negation only several months later. Stern & Stern (1937) argued that English-speaking children do not use the initial "*No"* to express a logical and truth-functional judgment, i.e. *"No, this is not the case"*, but rather to reject a previous statement "*No, I do not want that – No, it should not be like this".* This intuition has been later supported by Pea (1980), who maintained that the predominant meaning that children associate to negation during their first year of life is *prohibition* rather than a logical judgment. In fact, children would infer this meaning from parents' behaviour towards them: when children are doing anything wrong or dangerous, parents address them saying *"No"* and by shaking head.

During the single-word utterance period (and thus before being able to realize complete sentences) children use basic forms of syntactic negation to cover different negative functions, which gradually develop and appear later in children's multiword speech. Nevertheless, researchers have faced significant problems in understanding the psychological semantic categories of negation in this earliest period of language acquisition: since children do not make formal and syntactic distinctions between the negative expression used, psycholinguistic researchers can only suppose that the early meanings of negation are actually distinct in children's conceptual system. Assuming that it is almost impossible to build up a comprehensive typology of early meanings of negation, Pea (1980) proposed a categorization based on the similarities between the child's linguistic behaviours and the different situational contexts in which negation is used. Based on his longitudinal study on six English-speaking children, he identified three main *families* of possible negative meanings emerging during the single-word utterance period:

(43) a. **Rejection** – the child uses negation to reject an event, object, or person which is perceived in the immanent extra-linguistic context.
b. **Non-existence/Unfulfilled expectations** - the child uses negation to indicate the disappearance of something which was expected in the context but which is no longer perceivable.
c. **Truth-functional/Falsity** – the child negates the truth of a statement within a specific situational context. Negation is used to express the truth conditions of previous utterances produced by adults.

Longitudinal data show that rejection is the first semantic category of negation expressed by speech. Later on, children begin to make comments on the disappearance and non-existence of familiar objects and persons in the surrounding environment. Finally, at around two years of age, they begin to negate statements about the world, by using truth-functional negation. Pea (1980) interpreted this evidence by arguing that these three types of semantic negation involve an increasing development of abstract forms and cognitive representations, and, consequently, their use demand different levels of processing capacities. *Rejection* is used to express an attitude towards topics which are directly present in the situational context, and, therefore, there is no need for their internal and abstract representation. On the contrary, *non-existence* requires the abstract representation of the relevant object, which is no longer present in the context and must be denoted abstractly. The *truth-functional* meaning of negation requires an even higher level of cognitive representation: children must in fact simultaneously represent two different situations, one representing the actual state of the world, and one representing its false counterpart.

Given the difficulty in clearly understanding the real semantic categories of negative expressions used by children during the single-word utterance period, psycholinguistic researchers have mainly focused their attention on the development of negative meanings within children's multiword sentences. In her study on three American English-speaking children, Bloom (1970) found that the different semantic meanings of negation arise following the same sequential order within the multiword expressions produced by all the examined subjects. Based on this evidence, she identified three main categories of negative meanings, and argued that they emerge in child language in the following developmental order:

(44) a. **Non-existence** – a referent which is normally expected to exist in the child's belief world is not present in the extra-linguistic context. E.g., *No cookie* (In a box where children know there are usually cookies)

b. **Rejection** – a referent which exists in the extra-linguistic context is rejected or opposed by the child. E.g., *No dirty soap* (i.e., I do not want the dirty soap)

c. **Denial** – the negative utterance is used to assert that an actual or supposed predication does not hold. E.g., A car is given to the child and the adult says, *"This is a truck"*. The semantic meaning of the child's answer *"No truck"* is *"This is not a truck; this is a car"*.

As can be observed, there is a clear similarity between the two taxonomies proposed by Pea (1980) and Bloom (1970) concerning the categories of negative meaning employed by children[24]. However, different developmental orders have been found within these two early stages of language acquisition: while Pea (1980) gives priority to the emergence of *rejection* during the single-word utterance period, Bloom (1970) argues that *non-existence* is the first semantic meaning to be expressed in multiword speeches[25]. Nonetheless, these semantic categories are always acquired before *truth-functional negation* in both acquisitional stages. This further corroborates the assumption that the emergence of the different meanings of negation is directly related to the growth and development of children's cognitive representational abilities: expressing logical judgments about previous statements uttered by others involves in fact higher and more abstract levels of cognitive complexity than those required to refuse or indicate the absence of something that can be directly found in the extra-linguistic environment.

1.3.2 Emergence of different forms of negation

Two main types of negation can be distinguished in children's early multiword

[24] Volterra and Antinucci (1979) faced the issue of the emergence of negative meanings from a pragmatic perspective, arguing that the different meanings, which negation acquires in language use, are a consequence of the different kinds of pragmatic presupposition that the speaker assigns to the addressee. This work has been however largely criticized because of the excessive emphasis on the role of the addressee's presupposed set of beliefs as the trigger for the different negative meanings: according to Pea (1980), there is no evidence in fact that a child younger than 2 years of age would be able to infer successfully other people's complex set of beliefs.

[25] Bloom (1970)'s developmental sequence has been later endorsed by Choi (1988), who argued that, in order to successfully reject an object or an action, children can simply resort to one-word utterances because the referent is imminent and salient in the situational context. On the other hand, in *non-existence*, children have to make comments about referents that are no longer evident in the discourse context: as a consequence, children need to quickly develop negative forms in multiword speeches to convey adequately this semantic meaning.

production: *anaphoric negation*, which relates to the content of an earlier utterance (45), and *sentential negation*, in which the negative meaning applies to the sentence itself (46). Several studies on the acquisition of formal expressions of negation in child languages have shown that almost all the languages examined have specific and distinct lexical items for anaphoric and sentential negation: moreover, the former can occur either in isolation or in the initial position of a sentence following the negated one, whereas the latter usually occupies a sentence internal position (among others, Klima & Bellugi 1966, Bellugi 1967, Wode 1977, Choi 1988, Weissenborn et al. 1989, Deprez & Pierce 1993, Cameron-Faulkner et al. 2007).

(45) "This is red" "No [this is orange]"
(46) This is not red

Cross-linguistic studies have shown that anaphoric forms of negation are the first one to appear in child's language: in fact, there is a clear resemblance between the first negative words used by children and the anaphoric negative forms normally used in adult language; moreover, the negative marker is initially placed either in initial or final sentence position. This anaphoric priority is attributed to its greater frequency in the adult input, which allows children to master this form of negation very soon. However, it remains unclear whether children use these anaphoric negative forms, typical of adult language, only to express anaphoric negation or also as instances of sentential negation. In this respect, the data collected among different languages revealed a quite puzzling and heterogeneous situation. Weissenborn and colleagues (1989) showed that, in French, children never use the anaphoric form *non* to express sentential negation, which is normally expressed by *pas*: this is arguably due to the fact that these negative markers have fixed positions within the sentence, which might help children in discriminating between them. As in French, also in German anaphoric (i.e., *nein*) and sentential (i.e., *nicht*) forms of negation always occupy different syntactic positions. Nonetheless, Deprez and Pierce (1993) reported compelling evidence for an acquisitional phase in which German-speaking children consistently use the anaphoric form also to express sentential negation (e.g., *Ich nein schlafen*, lit. *I no sleep*). According to the authors, children would not simply overgeneralize using the negative form they firstly acquired, but they would rather prefer the anaphoric form over the sentential one due to its less phonetic complexity.

For what concerns English, Klima and Bellugi (1966) found that, during the earliest stages of language acquisition, children use interchangeably the anaphoric form *no* and the sentential form *not* in contexts in which only the latter is adequate: only after the acquisition of *n't* negative words (i.e., *can't, don't*), children would become able to distinguish between the two negative forms, using them in an adult manner. Based on this evidence, the authors hypothesized the existence of an acquisitional stage in which English-speaking children have not yet realized how to use the different expressions of negation within specific syntactic contexts. However, this hypothesis has been subsequently challenged by more recent experimental evidence. In fact, Cameron-Faulkner et al. (2007) demonstrated that the anaphoric *no* and the sentential *not* do not occur randomly in sentence internal position. If on the one hand English-speaking children initially use the anaphoric form to express sentential negation (e.g., *no move*, *no go*), on the other hand this tendency decreases at around two years and a half of age. At the same time, the correct use of the sentential form in the appropriate contexts starts to increase, and, by the age of three, *not* is finally the dominant form used by children to express sentential negation. Based on this evidence, Cameron-Faulkner et al. (2007) argue that English-speaking children do not go through an acquisitional step of completely random distribution of the negative lexical items. Instead, the temporary overlapping between the two different forms of negation would be the result of a conservative learning strategy: in the earliest stages of acquisition, children would simply tend to express new linguistic functions using lexical items already acquired such as the more familiar anaphoric form *not* also to express sentential negation in multiword productions.

1.3.3 Emergence of word order and distribution of negation

Once children have acquired the specific lexical items for the different forms of negation, they have to deal with the problem of how to combine these negative words within the sentences. Researchers have intensively studied the development of the position of sentential negative markers in languages such as English and German: in fact, during the earliest stages of acquisition, both these languages exhibit non-adult-like structures which are systematically used by children, leading to the assumption that they master the distribution of sentential negation through different developmental stages (among others, Klima & Bellugi 1966, McNeill & McNeill 1968, Bloom 1970, Wode 1977, Slobin 1985, Felix 1987, Van Valin 1991, Hummer 1993, Drodz 1995, Dimroth 2011).

Based on a longitudinal data collection, Felix (1987) proposed the following developmental sequence for the position of sentential negation in both English and German.

(47) Stage 1: Neg + S
a. No daddy hungry (Dad is not hungry)[26]
b. Nein spielen Katze (Cats don't play)

At this earliest stage, children express sentential negation by placing the negative

[26] This and the following examples are taken from Felix (1987).

word in sentence external position either before or after the negated sentence itself. Among the different possible explanations provided to account for this syntactic phenomenon (Bloom 1970, Drodz 1995, the most relevant), Klima and Bellugi (1966) argued that children would collocate negation in sentence external position in order to avoid interruptions in the core part of the sentence. Slobin (1985) and Van Valin (1991) proposed yet another solution: children would put the negative word in sentence external position to mark that negation takes scope over the entire proposition. In particular, according to Van Valin (1991), children would initially collocate negation outside of its scope domain because they arguably have a holophrastic representation of the syntactic clause. However, at a certain point in the development, they begin to conceive the sentence as being composed of different functional parts. During this second acquisitional stage, negation moves in sentence internal position in close proximity to the VP, as exemplified below:

(48) Stage 2: No/Nein + VP
a. Kathryn no like celery (Katrin doesn’t like celery)
b. Ich nein schlafen (I don’t sleep)

In addition, the forms like *can’t* and *don’t* start to appear in sentence internal position. However, their positive counterparts do not yet occur, suggesting that, in this phase, children are not interpreting *can’t* and *don’t* as negative auxiliaries but rather as unanalysed holophrases. Only later on, children use consistently sentence internal negation to express sentential negation:

(49) Stage 3: not/nicht + V; don’t + V; V + nicht
a. Kathryn not go over there (not + V)
b. I don’t go to sleep (don’t + V)
c. Eric nicht schlafen (nicht + V) (Eric doesn’t sleep)
d. Hennig brauch nicht Uni (V + nicht) (Henning doesn’t have to go to the university)

At this third developmental stage, children sometimes just omit the auxiliary and the copula, using the single negative marker to express sentential negation (e.g., *This not ice-cream*). In addition, although children now use the proper markers of sentential negation, they do not always place the negative word in the correct position within the sentence. There is in fact extensive evidence from German and English that children produce both pre-verbal and post-verbal internal negations (Wode 1976, Felix 1987, Clahsen 1988, Klein 2006, Jordens & Dimroth 2006). Dimroth (2010) argued that this variation is not attributable to problems with the placement of negation but rather it is closely related to children’s development of the concept of verb finiteness, which is acquired later than negation. Before morphological finiteness marking becomes productive, children would simply tend to reproduce the distributional patterns they hear from the adult input (Wode 1976, Jordens 2002): significantly, once that they have acquired this morphological regularity, they become instead perfectly able to raise finite thematic verbs to V2 position leaving the negation behind.

1.4 Concluding remarks

In this introductory chapter, we have outlined some of the most relevant issues addressed in the investigation of (sentential) negation. The discussion revealed an important mismatch between the simple syntactic nature of the negative operator in propositional logic and the formal, distributional and interpretative complexity of negative elements in natural languages. Throughout the chapter we have seen that linguistic negation interacts in significant ways with the semantic, pragmatic, and syntactic domains, as well as with the processes of language acquisition. In section §1, we showed that the part of the sentence which is affected by the domain of negation may vary, leading to different semantic interpretations. Moreover, there is an asymmetry between affirmative and negative sentences in both structure and use, with the latter requiring a specific context of utterance in order to be fully informative. In section §2, we have seen that languages display a lot of cross-linguistic variation in the ways in which they express sentential negation, and that the various negative elements have different syntactic properties (i.e., syntactic status and position within the clausal structure). Finally, in section §1.3, we have observed that children need time to master all the possible negative meanings and structures, which appear gradually in their repertoire from one year of age onwards. In addition, we have seen that the emergence of the different semantic negative meanings is arguably related to the development of children's computational resources, with truth-functional negation appearing at the very end of the acquisition process.

These general considerations regarding the complexity of the linguistic negation phenomenon pave the way to the investigation of how the presence of negation may affect the sentence comprehension process compared to the affirmative counterpart. In the next chapters, we will extend our considerations to this very intriguing and long-debated issue, that will be the core topic of this experimental work.

2 The processing of sentential negation

The processing of sentential negation has received a considerable amount of interest by cognitive scientists in the last fifty years. However, it is still under debate how quickly negation is processed and integrated into sentence meaning during online comprehension, as well as what is the role of the argument of negation[27] (i.e., the information occurring under its scope) in the interpretation process.[28] This theoretical debate will be discussed in detail in this chapter by reviewing the rich literature on negation processing. In the first section of the chapter (2.1) we will discuss the earliest experimental protocols investigating how the presence of negation affects the process of language comprehension. In the second part of the chapter we will provide an overview of two main theoretical accounts, i.e. the non-incremental (§2.2.1) and incremental (§2.2.2) models of negation processing. Although, as we will see, different theories of language comprehension fall within the same broad categorization, this general subdivision is motivated by how the different models account for the two aspects of the processing which are of central interest for the aforementioned theoretical debate and for the aim of the present study: namely, the moment in which negation is integrated into sentence comprehension, and the processing costs generally attributed to negative and affirmative statements. Throughout the chapter, experimental evidence in support or against the different processing accounts will be extensively evaluated.

2.1 Early studies on negation processing

The topic of negation processing has gained a great interest in the psycholinguistic community from the 1960s onward, and a significant amount of research in this field has been conducted. In early studies, different tasks were adopted with the aim of investigating how negation affects language processing and the comprehension of simple declarative sentences. Participants were asked to determine the truth-value of affirmative and negative sentences either against their pre-existing world knowledge (Eiferman 1961; Wason 1961; Wason & Jones 1963; Wales & Grieve 1969; Arroyo 1982) or against a picture, deploying the classical sentence-picture verification task set-up (Gough 1965; Trabasso et al. 1971; Clark & Chase 1972;

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[27] The term *argument of negation* will be used consistently throughout the dissertation to refer to the semantic and conceptual information occurring under the scope of negation.

[28] Unless otherwise specified, we will use the term *negation* or *negative sentence* to refer to sentential negation in standard declarative main clauses.

Carpenter & Just 1975). Regardless of the experimental design used, the results consistently indicated that negative sentences were more difficult to process than structurally similar affirmative sentences, as shown by longer reaction times and higher error rates for the former compared to those for the latter. Furthermore, the earliest experimental protocols on negation have shown that not only the polarity of the sentence but also its truth-value affects sentence processing in terms of response latencies and accuracy. In Wason's sentence verification task (1961), participants were asked to judge the truth-value of four types of sentences, based on their encyclopaedic world knowledge. The four sentence types were the following:

(1) a. 16 is an even number (true affirmative)
    b. 29 is an even number (false affirmative)
    c. 43 is not an even number (true negative)
    d. 62 is not an even number (false negative)

Behavioural results highlighted different aspects related to the processing. First, a significant effect of negation was found: negative sentences were more difficult to comprehend than affirmatives, as clearly indicated by overall longer reaction times and a lower accuracy. Second, sentence truth-value affected to some extent the processing, but, significantly, this effect was asymmetrical between affirmative and negative sentences. As a matter of fact, whereas among affirmative sentences false affirmatives took longer to process than true affirmatives, the opposite pattern was found among negative sentences, with participants being slower and less accurate in the evaluation of true negatives. All in all, these results showed the following asymmetry in the processing cost between the two polarity conditions: true affirmatives (a) > false affirmatives (b) > false negatives (d) > true negatives (c).

The same results were replicated by Carpenter and Just (1975), who investigated the processing of external negation through a sentence-picture verification task. In this experiment, participants were asked to evaluate the truthfulness of four types of sentences against different pictures. The four sentence types were the following:

(2) a. It is true that the dots are red (picture of red dots – true affirmative)
    b. It is true that the dots are red (picture of black dots – false affirmative)
    c. It is not true that the dots are red (picture of black dots – true negative)
    d. It is not true that the dots are red (picture of red dots – false negative)

As in Wason's experimental protocol (1961), significant effects of both polarity and truth-value were found. Negative sentences resulted more difficult to process than affirmatives. Moreover, among affirmatives, true affirmatives were the easiest to process. Conversely, the opposite pattern was found among negative sentences, with the corresponding true negatives being once again the most difficult, both in terms of accuracy and reaction times. Worth-noting, the similar pattern of results provided by these early studies on negation processing also suggests some common features underlying the processing of different types of syntactic negation, regardless of what the negative marker takes under its scope.

Different explanations have been proposed to account for the processing differences attested between affirmative and negative sentences. An intuitive proposal started from the consideration that negative sentences are phonologically longer than the corresponding affirmatives due to the presence of the negative operator in the syntactic construction. This extra length would be responsible for the higher processing cost of negative sentences. However, this assumption has rapidly been discarded by a series of studies conducted in the early 1970s. Just and Carpenter (1971) balanced the length of affirmative and negative sentences in terms of number of syllables: nonetheless, negation still resulted harder to process than affirmation. In addition, Clark and Chase (1972) compared the reading time of the negative operator with the different response latencies between affirmative and negative sentences. The comparison clearly showed that the reading time differences due to the presence of the extra phonological element were lower and hence not compatible with the different patterns of reaction times found between the two types of sentences. Other hypotheses took into account the higher syntactic complexity of negative sentences – following Chomsky's (1957) model of transformational grammar, and the psychological connotation of negation (which is believed to provide information in a more unpleasant way than positive sentences). However, both these explanatory attempts were discarded as they were deemed implausible for theoretical and empirical reasons (Gough 1966; Partee 1970).

Although the earliest works on negation processing discussed in this section have been widely criticized from a methodological perspective (see in particular Horn 1989), a large number of following studies have nevertheless confirmed this experimental evidence: i) negative sentences are harder to process than affirmatives, both in terms of reaction times and response latencies (Carpenter et al. 1999; Kaup et al. 2006; Kaup et al. 2007); ii) the truth-value of the sentence affects sentence processing, but, significantly, while the true value seems to facilitate the comprehension of affirmative statements, it slows down that of the negative ones (Kaup et al. 2005; Lüdtke et al. 2008; Vender & Delfitto 2010; Dale & Duran 2011). Leaving aside the first explanatory attempts here briefly discussed, these experimental findings have been accounted for within different theoretical accounts of negation processing, which can explain the slowness and greater difficulty of negative sentence interpretation in comparison with affirmative sentences. As we will discuss in detail in the following sections, behavioural data such as higher error rates and response latencies could be attributed to different possible aspects of negation processing, as for instance the need to first consider the affirmative counterpart during the interpretation of a negative statement (non-incremental models, 2.2), or the high pragmatic sensitivity to the communicative context in which negative statements are used (pragmatic models, 2.3.1). Moreover, counterintuitive data concerning the effect of truth-value have been taken as evidence for the Two-Step Simulation Hypothesis (§2.2.1.3). In the following sections we will discuss different theoretical models of negation processing, and how they account for the experimental evidence here reported.

2.2 Theoretical accounts of negation processing

The main theories of negation processing can be divided into incremental and non-incremental models. Although frameworks of negation processing vary along a number of dimensions, the subdivision between incremental and non-incremental models is a central one since it relies on two main features of negation processing: namely, the moment in which negation is integrated into sentence comprehension, and the processing costs attributed to negative and affirmative sentences. According to non-incremental models, the interpretation of a negative statement requires first the evaluation of the corresponding affirmative: as a consequence, extra processing resources and extra time are needed for the computation compared to affirmative sentences. Instead, incremental models assume that the semantic contribution provided by the negative operator is immediately integrated into the comprehension process: the processing of negative sentences would hence completely resemble that of affirmatives, with no extra time nor effort required.

As we will see in the following chapters, these two aspects of the processing (i.e., moment of integration of negation and processing costs) will be of central interest for the aim of the present study (§4): therefore, we will rely on this very general classification for the discussion of the main theories of negation processing.

2.2.1 Non-incremental models of negation processing

As briefly introduced in §2.2, non-incremental models agree on the assumption that negation is not immediately integrated into sentence comprehension: rather, the interpretation of a negative sentence requires first to consider its affirmative counterpart. This additional computational step would explain the higher processing costs which characterize negative sentences compared to affirmatives. Nevertheless, non-incremental models provide different explanations concerning how negation is applied to this positive representation.

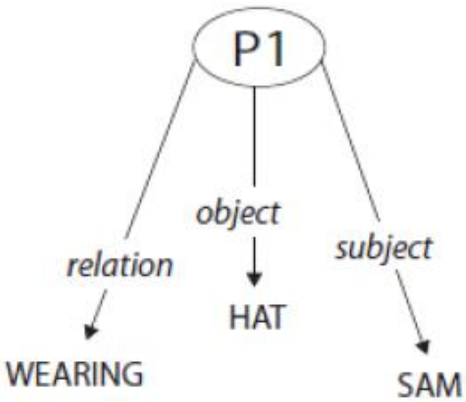
In this section, we will discuss three main theories of language comprehension which can be labelled as non-incremental: propositional theories (§ 2.2.1.1), discourse representation theories (§ 2.2.1.2), and the so-called Two-Step Simulation Hypothesis (§ 2.2.1.3). As we will see in detail, although all these three models can account for the general processing difficulty associated with negative sentences, propositional and discourse representation theories do not currently enjoy much support among researchers. On the other hand, a large number of psycholinguistic findings seem to support an experiential-simulation view of language comprehension, on which the Two-Step Simulation Hypothesis is grounded.

2.2.1.1 Propositional theories of language comprehension

Classical propositional theories (e.g., Trabasso et al. 1971; Kintsch and van Dijk 1978; Kintsch 1988; McKoon and Ratcliff 1992; among others) postulate that language comprehension involves propositional representations of the linguistic input, namely, representations of informational units carrying a truth-value. The core structure of these representational units is the proposition, which consists of one or more arguments, and a specific relation which holds between them. Consider, for instance, the following affirmative sentences:

(3) Sam is wearing a hat
(4) Sam bought Susan a hat

In propositional terms, sentence (3) consists of two arguments: there is a person, whose name is Sam, and an object, the hat. Between these two arguments holds the relation of wearing, in which Sam is the agent of the action, whereas the hat is the theme. On the other hand, in sentence (4) the relation of buying holds among three different arguments: as before, Sam and the hat – which play the same roles as in (3), and Susan, the person who is the recipient of the action of buying. For the aim of the present discussion, we provide below the propositional representation of (3)[29]:



[29] Sentences such as (3) resembles the type of declarative sentences which we adopted in our study (§4). The reader who is interested in further details on propositional representations should refer to the review by Kaup (1996). Example (3) and the relative representation are taken from Kaup (2006).

Figure 1.1. Propositional representation of an affirmative sentence

Propositional theories were the first model of language comprehension which assumed that the encoding of a negative sentence starts from the evaluation of its affirmative core. Negation is considered an overt linguistic operator that takes a whole proposition into its scope. Consider sentence (5), in which the proposition of Sam wearing a hat (3) is being negated.[30]

(5) Sam is not wearing a hat

The presence of negation projects a higher level of propositional representation (P2) in which the entire affirmative proposition (3) constitutes, as a unit, the argument of P2, and the negative operator represents the holding relation, as illustrated below.

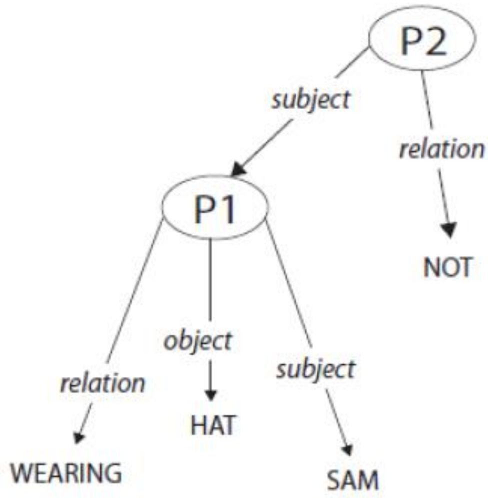


Figure 1.2. Propositional representation of a negative sentence

The propositional representation of the negative sentence in (5) is necessarily more complex than that of the corresponding affirmative in (3), as it contains both an extra proposition and an additional level of propositional encapsulation. The general processing difficulty associated with negative sentences is, therefore, due to this higher representational complexity, which results in higher response latencies and a lower accuracy at the behavioural level. Within this theoretical

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[30] However, consider for instance the sentence *Somebody did not leave*. Positive polarity items (PPIs) such as *somebody* do not scope under negation: in this example, negation does not apply to the entire proposition, and the only available reading is some > not (narrow-scope, NEG-V reading) $\exists x.\ person(x) \land \neg\ leave(x)$. (Baker, 1970; Giannakidou 1997, 1998; 2008; Szabolcsi, 2004; Nielsen, 2003; van der Wouden, 1994)

framework, MacDonald and Just (1989) tested the accessibility of concepts occurring under the scope of negation. In a probe-recognition task, participants were asked to read sentences like (6): then, they had to decide whether a certain lexical element (e.g., cookies, bread) was present in the sentence they just had read.

(6) Almost every weekend, Mary bakes some bread but no cookies for the children

Results showed that concepts presented under the scope of negation were less available after reading than non-negated elements, as indicated by significantly longer response latencies for the recognition of the negated term *cookies* than for *bread*. The researchers accounted for this evidence by postulating that when the information occurring under the scope of negation is encapsulated into a higher level of propositional representation, its lexical accessibility is reduced. After an initial processing insensitivity to negation, due to the evaluation of the affirmative propositional core, the parser's attention shifts away from the information under the scope of negation towards an alternative. As a consequence, the negated information becomes less accessible than the very same information in the corresponding affirmative sentence.

Although negation is essentially considered an accessibility reducing operator, Kaup (1997) claimed that the situational context in which negative sentences are presented has direct consequences on this inhibitory effect of negation. In particular, they suggested that the lower accessibility of negated terms is also determined by the presence of the corresponding concepts in the described state of affairs. Consider sentence (6) from MacDonald and Just's (1989) probe-recognition task: whereas the bread (i.e., the non-negated element) was effectively present in the outlined situational context, the cookies (i.e., the negated element) were not. To test this hypothesis, Kaup (1997) developed a follow up of the experiment by MacDonald and Just, introducing two types of predicates: verbs referring to an idea of creation (7), and verbs referring to an idea of destruction (8).

(7) Every weekend Mary bakes some *bread* but no *cookies*.
(8) Elizabeth tidied up her drawers. She burned the old *letters* but not the *photographs*.

This experimental set-up allowed Kaup and colleagues to balance the effective presence of the negated and non-negated probes in the described situation. Verbs of creation (e.g., bake) entail the presence of the non-negated term (e.g., bread) but not that of the negated element (e.g., cookies): in order to comprehend (7), the parser has to construct the mental simulation of the expected state of affairs (e.g., Mary baking both bread and cookies) and compare it with the mental simulation of the actual state of affairs (e.g., Mary baking only bread). Verbs of destruction (e.g., burn) entail the presence of the negated element (e.g., photographs) in the described situation but not that of the non-negated term (e.g., letters): to comprehend (8), the parser has to construct an expected state of affairs in which there are neither letters nor photographs (as a consequence of the lexical properties of the verb); this expected state of affairs must then be compared with the actual situation in which there are only photographs in the drawers. As demonstrated by MacDonald and Just (1989), the results further confirmed that negated terms are less accessible than non-negated ones with verbs of creation, as the former were recognized more slowly than the latter. Instead, no differences in recognition latencies were found between negated and non-negated terms with verbs of destruction. In this case there is no reduced accessibility to the negated entity since it is present in the simulation of the actual state of affairs. Moreover, both the photographs and the letters must exist in order to be destroyed, whereas such presupposition of existence is lacking with verbs of creations[31]. All in all, these findings clearly indicate that word accessibility in negative sentences is strongly influenced not only by the presence of the negative operator but also by the lexical properties of the verb: the situational context in which negative sentences are presented can, therefore, significantly affect the processing.

To conclude, classical propositional theories assumed a lesser accessibility of the concepts occurring under the scope of negation, which has been confirmed by many subsequent studies on the issue (Giora et al. 2005; Hasson & Glucksberg 2006; Kaup et al. 2007; Ferguson et al. 2008). In addition, experimental evidence has suggested that this inhibition power associated with negation is not automatic but rather highly depending on the discourse context (Giora et al 2007; Mayo et al. 2004; among others). This experimental evidence and the underlying theories of negation processing will be discussed later in the chapter.

2.2.1.2 Representational models of language comprehension

Propositional theories and representational models of language comprehension such as discourse-representation theory (Kamp 1981) and situational-mental models (Dijk & Kintsch 1983; Johnson-Laird 1983; Morrow et al. 1990) agree that negative sentences are computed by applying the negative operator to the representation of the positive state of affairs. Nevertheless, they assume linguistic representations to have a different nature: while propositional representations are considered descriptions of the state of affairs in a specific mental language, referential representations are intended as actual representations of the situation itself. According to representational models, language comprehension consists in creating a referential representation of the linguistic input: the sentence is converted

[31] Nevertheless, the authors recognized important differences in the lexical properties of the verbs adopted, which made it difficult to draw definitive conclusions from the study.

in a referential level composed by mental tokens and propositions. Mental tokens are the core structure of the referential representation, and correspond to the referents of the linguistic input. The intervening relations and the properties of these tokens are assigned by the propositions. For ease of reference consider again the affirmative sentence *Sam is wearing a hat*. Both situational-mental models and discourse-representation theory interpret the sentence as a referential representation composed by two tokens: x, which corresponds to the person named Sam, and y, which corresponds to the hat. Between these two tokens the relation of wearing holds: as x occupies the first position in the relation, Sam is considered to be the subject of the action of wearing, whereas the hat to be the object.

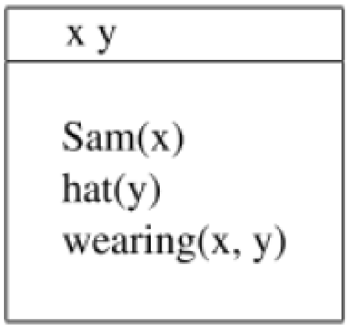

Figure 1.3. Referential representation of an affirmative sentence in discourse-representation theory

In the referential representation of the sentence *Sam is not wearing a hat* the negative linguistic operator applies to a subordinate representation. However, negation does not take under its scope the whole situation described (i.e., both the tokens and the undergoing relation between them) as in propositional theories. As illustrated in Figure 1.4, negation takes scope over the relation of *wearing* and the token corresponding to the referent *hat*. Consequently, while the accessibility of the referent *hat* is reduced, the referent *Sam* is perfectly accessible to the parser, as only the first of the two elements occurs under the scope of the negative operator.

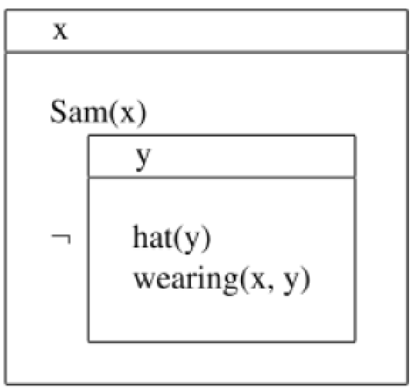

Figure 1.4. Referential representation of a negative sentence in discourse-representation theory

To summarize, similarly to propositional theories, representational models of language comprehension account for the increased processing difficulty found in negative sentences in comparison with affirmatives as direct consequence of the more complex referential representation involved: the more complex the representation is, the more processing time is required to compute it, and the more difficult are the parsing processes involved in the computation. Both these models assume a reduced accessibility of the negated concepts, encapsulated into a higher level of either propositional or referential representation: however, they make different predictions with respect to the availability of the referents in the negative sentence. Nevertheless, although non-incremental models described so far can explain why negation affects sentence processing in terms of longer response latencies and lower accuracy, they seem unable to capture the additional information that the negative sentence provides with respect to the described state of affairs (Kaup et al. 2006). Consider, for instance, the sentence *The door is not closed*. In propositional theories of language comprehension (§2.2.1.1), the information occurring under the scope of negation is rejected by tagging the affirmative proposition (9) as not-holding for the state of affairs under consideration (10):

(9) closed [door]
(10) not [closed [door]]

However, the negative sentence *The door is not closed* carries additional information which cannot be conveyed by a propositional representation of the sentence such as (10): not only it presupposes the existence of a particular door in the described state of affairs, but it also implicitly specifies that the door under consideration is open. Similar considerations can be made for representational theories of language comprehension (§2.2.1.2), in which negation is applied to the embedded referential representation of the negated state of affairs. Since the core structure of a referential representation consists of the referents of the linguistic input and the relations holdings among them, the mental representation of the sentence *The door is not closed* includes the presupposition concerning the existence of a door in the situation described. However, the inference that the door under discussion is actually closed is optional, and may not necessarily be conveyed by the referential representation of the sentence itself.

Furthermore, as a growing number of psycholinguistic studies is reporting evidence for an experiential view of language comprehension, these theoretical models based on either propositional or more abstract mental representations do not currently enjoy much support among researchers. In fact, as we will see in detail in the next section, the experiential-simulation model of language comprehension

(Zwaan & Radvansky 1998) considers the mental simulations involved in sentence processing to be grounded on non-linguistic cognitive processes such as perception and action.

2.2.1.3 An experiential-simulation model of language comprehension

More recent psycholinguistic research has provided a consistent body of empirical evidence in support of an experiential view of language comprehension. Proponents of this account claim that the mental simulations involved in language comprehension are neither propositional (as in propositional theories §2.2.1.1) nor empty discourse representations (as in representational models §2.2.1.2) but rather experiential in nature, as they are grounded on non-linguistic cognitive processes (e.g., perception, action). According to this view, sentence comprehension involves a mental simulation of the described state of affairs, which is very close to a direct experience of the situation itself (the so-called *situational model*, Zwaan & Radvansky 1998). Neurological studies have corroborated this hypothesis, showing the existence of a significant overlap between the mental subsystems involved in the representation of linguistic information and those used in other non-linguistic cognitive processes such as action planning, perception, and imagery (Pulvermüller et al. 2001; Pulvermüller 2002; Zwaan & Taylor 2006). In addition, behavioural data indicate that language comprehension leads to the creation of representations in those mental subsystems involved in the aforementioned non-linguistic cognitive processes (see Zwaan 2004; Kaup et al. 2007 for a review). Further evidence pointing in the same direction comes from neurolinguistic studies which have demonstrated that motor processes are active during the comprehension of linguistically conveyed information (Ghio & Tettamanti 2010; Tettamanti & Buccino 2005; Tettamanti et al. 2008; Papeo et al. 2012; among others).[32]

The Two-Step Simulation Hypothesis (Kaup et al. 2007)

The interpretation of negative sentences constitutes a potential problem for the experiential-simulation view of language comprehension. By definition, negation is a linguistic operator that does not have an equivalent in the experiential world: as a consequence, negative sentences cannot be represented explicitly in non-linguistic simulations, as occurs instead with affirmative statements. To overcome this theoretical impasse, Kaup et al. (2007) proposed the so-called Two-Step Simulation Hypothesis. This model of language comprehension is grounded on a pragmatic

[32] Although the findings reported by these works have been interpreted as against a non-incremental view of language processing, these neuro-linguistic studies have been mentioned in this section merely as evidence of the activation of motor and sensory brain areas during language comprehension. The theoretical implications of these studies will be analysed in detail in §2.2.2.2

view of negation according to which negative sentences are fully informative when used to express a deviation from a presupposition or expectation established in the communicative context (Wason 1959,1961; Givòn 1978; Horn 1989). Consider, for instance, the sentence below:

(11) My shirt is not blue but dark green

Although this negative sentence is grammatically correct and potentially true, it would nevertheless sound unusual in some communicative contexts, as for example, if uttered as answer to a sentence like (12):

(12) What colour is your shirt?

Kaup and colleagues observed that negative statements are generally used to deny a corresponding positive presupposition attributed to the listener. Indeed, the very same sentence in (11) can be uttered felicitously in a context in which the t-shirt was believed to be blue, as for example in (13):

(13) What a nice shirt you have, is that blue?

Here, the negative sentence in (11) is used to reject a previous assertion made by another speaker, and, therefore, its felicity conditions are fully satisfied. More detailed considerations concerning how the pragmatic felicity of the context can affect the processing of negative sentences will be discussed later in the chapter. At this point of the discussion, we mainly want to underline how, intuitively, negation seems to require first a deletion of a previous expected state of affairs (e.g., the t-shirt being blue), and later its replacement with the representation of the actual state of affairs (e.g., the t-shirt being dark green), in order to be used appropriately.

Based on these considerations, the Two-Step Simulation Hypothesis claims that the comprehension of negative sentences involves two temporally distinct stages. At first, the comprehender retrieves (or constructs, in unsupportive contexts) the mental simulation matching the positive situation described in the sentence (e.g., the negated state of affairs). Then, she constructs instead a simulation corresponding to the actual meaning of the sentence (e.g., the actual state of affairs). The comparison between these two mental simulations and their subsequent discrepancy leads the comprehender towards the comprehension of the sentence negative meaning. Therefore, this model claims that in the interpretation of affirmative and negative sentences, the processing of the latter requires the creation of two different mental simulations. For illustrative purposes consider the following example in Kaup et al. (2006):

(14) The door is open
(15) The door is not open

In the positive state of affairs described in (14) the door is open: according to the experiential view of language, the comprehender would mentally simulate the representation of an open door. Instead, in the negative state of affairs described in (15), the door is not open. The Two-Step Simulation Hypothesis predicts that, in order to understand what is being negated, the comprehender first simulates the negated state of affairs, i.e., the door open. Then, she simulates the actual state of affairs, i.e., a door closed. From the comparison of the two different mental simulations the comprehender can reconstruct the negative information conveyed by (15), namely that the door is closed. The representation of the negated state of affairs is not integrated with that matching the actual state of affairs: rather, it is kept separate in an auxiliary representational system and, after the comparison between the two simulations, it is rejected.

In line with the other non-incremental accounts, the Two-Step Simulation Hypothesis assumes that the comprehension of negative sentences is grounded on more complex mental representations than the corresponding affirmative sentences, and, hence, it makes similar predictions with respect to the general processing difficulties associated with negation. According to the experiential-simulation view, the processing of negative sentences consists of two temporarily distinct and subsequent stages, which corresponds to the construction of two different mental simulations of the negated and the actual state of affairs, respectively. On the other hand, affirmative sentences require the construction of only one mental simulation, directly matching the state of affairs described in the affirmative statement. The extra processing step required with negative sentences is sufficient to account for the fact that, as largely attested, negative sentences generally require a much more costly processing than the corresponding affirmatives. In addition, the Two-Step Simulation Hypothesis also predicts an initial insensitivity to negation during the processing[33], due to the retrieval/construction of the simulation corresponding to the negated state of affairs (i.e., the positive situation) in the first stage of negative sentence processing.

Relevant experimental findings

A series of studies conducted by Kaup and colleagues provide supporting evidence for these theoretical assumptions, showing that negative sentences require the

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[33] Given the experiential nature of the simulations involved, negation cannot be explicitly represented as an overt linguistic operator but, rather, it must be assumed to be implicitly encoded in these non-linguistic mental simulations. Negation is therefore initially parsed but held back to be encoded only in the second stage of the processing, since the negative meaning of the sentence is captured in the deviation between the experiential simulations of the negated and the actual state of affairs.

elaboration of two subsequent mental representations, and that, significantly, negation affects only the second one. In Kaup et al. (2005), they developed a sentence-picture verification task in which participants were presented with affirmative and negative sentences such as (16) and (17):

(16) The lion is above the dolphin
(17) The lion is not above the dolphin

The sentence was followed by pictures of the two mentioned entities, placed one above the other (Figure 1.5): the spatial arrangement of the two pictures could either match the actual state of affairs (e.g., a dolphin below a lion in the affirmative sentence, and a dolphin above a lion in the negative sentence) or not (e.g., a lion below the dolphin for the affirmative sentence, and a lion above the dolphin in the negative sentence). Participants were asked to decide whether the depicted objects corresponded to the entities mentioned in the sentences. Note that, across all the test sentences, the pictures were always matching the mentioned entities: the difference consisted only in their spatial arrangement within the visual context. Moreover, for negative sentences, when the picture mismatched the situation described in the sentence, it matched instead the negated state of affairs described by the sentence itself. The time presentation of the visual stimuli was manipulated so that participants were presented with the pictures with a variable delay of 750ms and 1500ms after the sentence onset.

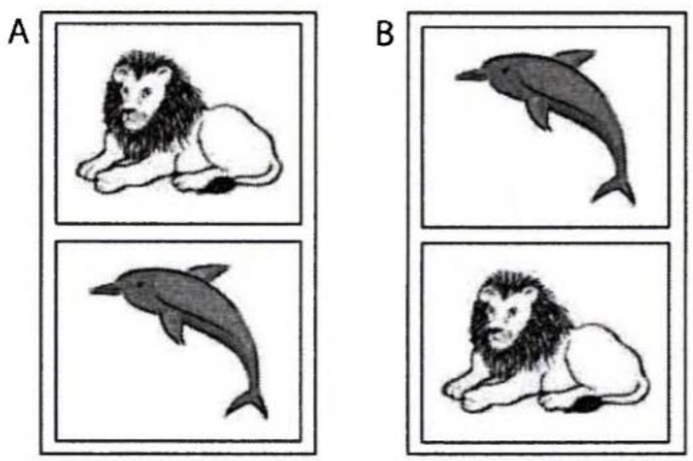

Figure 1.5. Example of visual stimuli employed in Kaup et al. (2005)

Results showed a matching effect in the 750ms delay condition but, significantly, only with affirmative sentences: shorter response latencies were found when participants were at first presented with the sentence *The lion is above the dolphin* and then with the picture describing the very same situation, namely a lion above a dolphin. On the contrary, the opposite pattern was found in this condition with negative sentences: after having been presented with the sentence *The lion is not* *above the dolphin*, participants were slower in the recognition task when the pictures matched the described state of affairs (i.e., the dolphin above the lion) than when they corresponded to the negated situation (i.e., the lion above the dolphin). Interestingly, in the 1500ms delay condition, participants were faster with a matching scenario than with a mismatching one in both polarity conditions. To summarize, the reaction time pattern was consistent among affirmative sentences regardless of the delay in picture presentation. Instead, the processing of negative sentences was facilitated by a mismatched scenario (corresponding to the negated situation) in the short delay condition, and by a matched scenario (corresponding to the actual situation) in the long delay condition.

Similar evidence has been reported in subsequent works. Using a self-paced reading paradigm, Kaup et al. (2006) investigated the interpretation of contradictory predicates. Participants were asked to read affirmative (e.g., *The door is open*) and corresponding negative sentences (e.g., *The door is not open*). Subsequently, they were presented with a picture of the target entity that could either match or not the entity presented in the sentence. As in Kaup et al. (2005), the pictures always matched the mentioned entities, but their properties could be consistent or not with those described in the sentence. For instance, for the negative sentence *The door is not open*, the picture could represent either a closed door (matching condition) or an open door (mismatching condition). Again, for negative sentences, the mismatching picture corresponded to the negated state of affairs described by the sentence itself. In the recognition task, participants were asked to say out loud the name of the depicted object. A variable delay of 750ms and 1500ms was introduced between the presentation of the sentence and that of the picture. The previous results by Kaup et al. (2005) were confirmed also with contradictory predicates. After 750ms of delay, a matching effect between the picture and the sentence was found only with affirmative sentences: when participants were presented with the sentence *The door is open*, they were faster in naming the entity against the picture representing the actual situation (i.e., an open door). Significantly, in this short delay condition, a matching effect was not found among negative sentences: presented with the sentence *The door is not open*, participants were faster in the recognition task with the picture of an open door, depicting the negated situation. Instead, after 1500ms of delay, response latencies were shorter when negative sentences were followed by the picture depicting the actual state of affairs (i.e., a closed door).

Further consistent findings were reported in Kaup et al.'s (2007) study on the interpretation of definite and indefinite negative sentences.

(18) There was no eagle in the sky
(19) The eagle was not in the sky

In a sentence-picture verification task, participants were asked to read negative sentences as (18) and (19). Once again, after reading, they were presented with a picture either representing the actual (e.g., an eagle in the nest) or the negated state of affairs (e.g., an eagle in the sky). The task consisted in judging whether the depicted object had been mentioned in the sentence. As in the previous experiments, the picture always depicted the mentioned entity, but it could differ with respect to the shape or the spatial arrangement. For instance, after the negative sentence in (18), the depicted eagle could be either in the nest (matching condition) or with outstretched wings, and hence assumed to be flying in the sky (mismatching condition). Again, for negative sentences the matching and mismatching conditions corresponded to the representations of the actual state of affairs and of the negated one, respectively. The results replicated the previous findings (Kaup et al. 2005; 2006): participants were faster in the recognition task when the picture matched the negated state of affairs (i.e., an eagle with outstretched wings). The same pattern of response latencies was found with both types of negative sentences.

This consistent pattern of findings provides evidence that the comprehension of negative sentences consists of two distinct stages, and negation is integrated only later in the processing. In all the experiments discussed, the results for negative sentences showed that, in the short delay condition, the processing was facilitated when the picture matched the corresponding positive situation. This early facilitation effect has been attributed to the fact that, in order to understand a negative sentence, participants initially simulate the positive representation of the argument of negation, being hence faster in its later recognition at this time of the processing[34]. After 750ms the comprehender is still focusing on the contrafactual state of affairs, indicating that negation has not been integrated yet in the processing. Instead, in the long delay condition, the facilitation effect is present with the picture matching the actual situation. This indicates that negation has been now integrated in the interpretation process, and the comprehender has modified its mental simulation accordingly. On the other hand, with affirmative sentences the facilitation effect was always found in the matching condition. This finding is consistent with the assumption that the comprehension of affirmative sentences requires only the simulation of the actual state of affairs, described in the sentence and explicitly represented in the experiential world. The results by Kaup et al. (2007) can be accounted accordingly: after sentence presentation, participants were faster in recognizing the entity when the picture matched the negated situation because the first temporal step in the processing consists in the elaboration of this very same state of affairs, which is consistent with the picture presented. Therefore,

[34] However, Papeo et al. (2012) observed that this priming effect only demonstrates that the representations of the positive picture (i.e., a flying eagle) and the negated situation (i.e., an eagle in the sky) do share some features, not that they are identical. According to the authors, a similarity between the representation of an eagle in the sky and that of an eagle with outstretched wings would be sufficient to induce the observed priming effect.

during the earliest milliseconds, meaning computation is still insensitive to the presentence of negation, which has not been elaborated yet.

All in all, this experimental evidence speaks in favour of a late, non-incremental integration of negation, caused by the extra processing step required in negative sentences in comparison with affirmative sentences. The need to construct and compare two different mental simulations is sufficient to explain the higher processing difficulties associated with negative sentences.

Evidence of a different sensitivity to negation between early and late stages of sentence processing has been attested also by a behavioural study on metaphors. Hasson and Glucksberg (2006) employed a lexical decision task to investigate the interpretation of affirmative (20) and negative metaphorical sentences (21).

(20) The lawyer is a shark
(21) The lawyer is not a shark

After reading the sentences, participants were asked to make a decisions about different adjectives that could be related to the meaning of the affirmative metaphor (e.g., *cruel* for sentence (20)), to that of the negative one (e.g., *gentle* for sentence (21)), or to none of them (e.g., *happy*). Participants were divided into three groups, each of which corresponded to a different time delay between the presentation onset of the metaphorical sentence and that of the target adjective (150ms, 500ms, 1000ms). Significantly, no effect of negation was found during the early stages of sentence processing. In the 150ms and 500ms delay conditions, results showed a facilitation effect for lexical decision when the adjective was related to the positive state of affairs, both in affirmative and negative sentences. On the other hand, in the 1000ms delay condition, the very same facilitating effect was attested only after the presentation of affirmative metaphors. These results clearly indicate that the processing of negative sentences initially resemble that of affirmatives, with negation being processed and interpreted only at around 1000ms after sentence presentation.

Experimental findings from EEG-ERPs studies

Further evidence of a non-incremental processing of negation has been reported by a series of EEG-ERP studies, in which the brain response to a stimulus (either sensory or cognitive) is measured by means of electroencephalography.[35] Fischler

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[35] Electroencephalography (EEG) is a non-invasive electrophysiological technique to record spontaneous electrical activity in the brain. Multiple electrodes placed on the patient's scalp record voltage alterations resulting from ionic current within neurons in specific brain areas. The analysis generally takes into consideration event-related potentials (ERPs), that describe potential voltage alternations time-locked to the presentation of either physical or conceptual stimuli. EEG and the

et al. (1983) conducted a sentence evaluation task on healthy adults, who were asked to read negative sentences and establish their truth-value based on world-knowledge within 1000ms after reading. The test sentences were either semantically congruous (22) or incongruous (23). Note that although *robin* and *bird* belong to the same semantic field[36], the presence of negation makes sentence (23) incongruent as it denies the semantic relation. Conversely, sentence (22) can be considered semantic congruent because negation confirms that *robin* and *tree* do not belong to the same semantic field.

(22) A robin is not a tree (congruent condition)
(23) A robin is not a bird (incongruent condition)

The analysis of the event-related potentials showed that the final word elicited larger N400 amplitudes (generally associated with the detection of semantic incongruency and violations) in the semantically congruous condition. This effect is a strong evidence that during the early stages of sentence comprehension negation is not yet integrated in the processing: the negative sentence in (22) is initially processed as the corresponding affirmative *a robin is a tree*, hence the semantic violation resulting in a larger N400 effect.[37]

These results were further corroborated by Lüdtke et al. (2008), who developed a sentence-picture verification task to investigate ERP correlates during and after the reading of affirmative and negative sentences. Typically developed German-speaking adults were presented with German sentences, here translated in English:

(24) In front of the tower there is a ghost
(25) In front of the tower there is no ghost

On each trial, the sentences were visually presented to the subject, followed by a matching (e.g., a ghost in front of a tower) or mismatching picture (e.g., a lion in front of a tower). There were four experimental conditions based on the combination of visual and linguistic stimuli (Figure 1.6): True Affirmative, False Affirmative, True Negative, False Negative.

ERP analysis have been widely adopted in the study of language comprehension because of their very high temporal resolution (< 1ms).

[36] A semantic field is a set of words (or lexemes) related in meaning which cover a certain conceptual domain and which bear certain specifiable semantic relations to one another (Lehrer, 1985)

[37] Note, however, that the proximity of the nouns in the test sentences might have determined lexical priming effects that can affect the ERP latencies.

Sentence	*Picture*
True affirmative (TA) *In front of the tower there is a ghost.*	
False affirmative (FA) *In front of the tower there is a ghost.*	
True negative (TN) *In front of the tower there is no ghost.*	
False negative (FA) *In front of the tower there is no ghost.*	

Figure 1.6. Examples of stimuli in Lüdtke et al. (2008) – translated in English from German

Participants were asked to judge whether the meaning of the sentence corresponded to the depicted situation. Note that the truth-value of the sentence cannot be determined based on encyclopaedic knowledge as in Fischler et al. (1983), but only in relation to the following picture. Worth noting, in the True Negative and False Negative conditions the visual stimuli corresponded to the representations of the actual state of affairs and of the negated one, respectively: as shown in Figure 1.6, in the former there is a lion instead of a ghost in front of the tower, whereas in the latter the ghost itself is in front of the tower. The experimental items were divided in two time-conditions: in half of the trials the picture was displayed 250ms after sentence reading (short delay condition); in the other half, the picture presentation onset occurred 1500ms after the linguistic stimulus. Both response latencies and event-related potentials were considered. In the short delay condition, N400 activations showed a priming effect independent of the presence of negation: when the depicted object was mentioned in the sentence, the N400 amplitude was smaller, regardless of the sentence truth-value. That is, the false negative condition showed a smaller effect of semantic incongruence than the true negative condition, although being contextually false.

This pattern of results is consistent with the findings reported by Fischer et al. (1983): in the early stages of sentence comprehension, the processing is primed by the presence of the mentioned object because negation has not been integrated yet, and the processing of the negative sentence resembles that of the corresponding affirmative. In addition to this priming effect, a robust interaction effect between truth-value and polarity was found in the long delay condition. Among affirmatives, a larger N400 effect was enhanced in the false condition (e.g., with a lion in front of the tower). Conversely, among negative sentences, a larger amplitude was detected when the sentence was contextually true, but the final word was incongruent with the depicted picture (e.g., with a lion in front of a tower). As concern response latencies, previous behavioural data (Wason 1961; Carpenter & Just 1975; among others) were confirmed. Negative sentences take longer to process than the affirmative ones, and among negatives the true negative condition is the most demanding in terms of processing costs. Moreover, the N400 smaller amplitudes are correlated with the shorter response latencies in both the delay conditions, namely with true affirmative and false negative sentences.

Taken together, the reported findings strongly speak in favour of the experiential-simulation view of comprehension. As a matter of fact, the Two-Step Simulation Hypothesis not only accounts for the overall processing difficulties found in negative sentences, but it also predicts the negation-by-truth-value interaction reported across behavioural and EEG studies deploying sentence-picture verification tasks (Kaup et al. 2005; 2006; 2007; Lüdtke et al. 2008). As discussed above, negative sentence comprehension is assumed to involve two distinct simulations: a simulation of the negated state of affairs and the subsequent simulation of the actual state of affairs. This assumption directly implies that during the early stages of negative sentence processing the comprehender can benefit from being presented with a picture that depicts the negated state of affairs, and that hence corresponds to the mental simulation under construction. This is the case of the false negative condition, where the sentence *In front of a tower there is no ghost* is followed by a picture representing the negated state of affairs (i.e., a ghost in front of a tower). This picture has a facilitating effect on the computation because it primes the mental representation that the comprehender is constructing during the early moments of sentence comprehension. Instead, in the true negative condition, the picture corresponds to the actual state of affairs (i.e., a lion in front of a tower): the mismatch between the mental simulation being created and the picture provided does not produce any facilitation effect on the processing, rather it probably interferes with it. Therefore, shorter response latencies and smaller N400 amplitudes associated with false negative sentences compared to true negative ones seem to be determined by a priming effect produced by the correspondence between the visual scenario and the mental simulation involved in the first step of sentence comprehension. Similarly, the classical effect of truth-value attested in affirmative sentences can also be explained in terms of priming between the mental representation involved in the processing and the visual stimulus provided. According to the experiential-simulation view, the affirmative sentence *In front of the tower there is a ghost* requires the construction of only one mental simulation, corresponding to the described situation (i.e., the ghost in front of a tower). This simulation has its visual equivalent in the picture provided in the true affirmative condition, that, therefore, has a facilitation effect on the processing.

Nevertheless, Lüdtke et al. (2008)'s study has been largely criticized by Nieuwland and Kuperberg (2008), who underlined how the experimental design lacks a proper supportive context in all the experimental conditions. Quite intuitively, Figure 1.6 shows how the pictures adopted in the four conditions do not have the same discourse relevance with respect to the corresponding sentences. In the case of true affirmative and false negative sentences, the picture is perfectly relevant within the discourse context: in the former, it depicts the described situation; in the latter it represents the entity being denied, justifying, from a pragmatic perspective, the use of negation in the sentence. On the other hand, in the case of false affirmative and true negative sentences, the picture is significantly less relevant in the discourse context: in particular, in true negative sentences the comprehender might be confused by the fact that negation is used to deny the presence of an entity which is not even relevant in the discourse context, determining a sense of weak pragmatic adequacy. Worth noting, the true negative condition has been largely reported by Lüdtke and colleagues - and in classical sentence picture verification task studies, as being the most demanding in terms of processing costs. Nieuwland and Kuperberg (2008) have hence claimed that the N400 amplitudes and longer response latencies associated in particular with true negative sentence interpretation might be affected by the absence of a congruent and felicitous visual context.

However, the experiential-simulation view of language comprehension is not incompatible with findings showing that increased processing costs are reported when negative sentences have to be interpreted in pragmatically infelicitous contexts (Lüdtke and Kaup 2006; Kaup 2006). On the contrary, this can be considered perfectly in line with the predictions made by this account, which grounds on a pragmatic view of negation and hence considers negative sentences fully informative when used to express a deviation from either a presupposition or an expectation (Wason 1959,1961; Givòn 1978; Horn 1989). According to the Two-Step Simulation Hypothesis, the processing of negative sentences always requires to first evaluate the representation of the negated situation. Crucially, this happens independently of the discourse context. When negative sentences are uttered in isolation or in unsupportive contexts, they are assumed to take longer to process than the corresponding affirmative sentences because two mental simulations must be created. In order to understand sentence (26), the comprehender has first to construct a simulation of the expected state of affairs (i.e., Lisa's husband preparing dinner); then she has to create the mental simulation of the actual situation (i.e., Lisa's husband not preparing dinner but doing something else), to adjust the former accordingly.

(26) When she arrived home, Lisa realized that her husband was not preparing dinner.[38]

Hence, the comprehension of negative sentences presented in unsupportive contexts is expected to be more difficult and more demanding in terms of processing resources, since it requires the creation of two different mental simulations *ex novo*. Instead, when the negative sentence is uttered in a pragmatically felicitous context, the comprehender has already available a simulation of the negated state of affairs, either explicitly mentioned in the discourse or inferred on the basis of the comprehender's general knowledge. In (27), the context provides the comprehender with the information that Lisa is expecting her husband to prepare dinner. The simulation of the negated state of affairs is given by the presupposition established in the discourse context: as a consequence, the comprehender only has to correct the expectation by simulating the actual state of affairs.

(27) Lisa finished late working. While she was driving home, she thought that her husband was preparing dinner. But when she arrived home, she realized that her husband was not preparing dinner.[39]

Therefore, negative sentence comprehension is assumed to be less difficult in pragmatically felicitous contexts because the first of the two mental simulations required in the processing must not be created *ex novo*: rather, it can be easily retrieved by the discourse situation. In the classical sentence-picture verification set-up, the discourse context consists in the visual scenario provided together or after sentence presentation. Accordingly, the relationship between context adequacy and the negation-by-truth-value effect found across a large number of these studies can be explained in the same terms.

Consider again Lüdtke et al. (2008)'s stimuli. In the false negative condition, the visual scenario provides the representation of the negated state of affairs. The comprehender is hence facilitated in evaluating the truthfulness of the negative sentence because the first mental simulation required in the processing is already available in the context and must not be created from the scratch. On the other hand, the visual context in the true negative condition is pragmatically infelicitous, as it does not provide any support for the reconstruction of the negated situation simulation. As a consequence, the comprehension process is slowed down by the necessity to construct *ex novo* the representation of the negated state of affairs rather than retrieve it from the communicative context. This view is in line with Deutsch et al.'s (2006) considerations concerning the relationship between working memory resources and sentence processing. The computation of negative sentences is

[38] From Kaup et al. (2007b)
[39] ibid.

considered not too demanding when working memory resources are not overloaded. However, negation processing becomes significantly more challenging in terms of processing resources when the execution of other working memory tasks is underway. Following this reasoning, when negative sentences are uttered in felicitous pragmatic contexts (e.g., false negative condition), the context provides a significant support to the simulation of the negated state of affairs: hence, negative sentence interpretation is not extremely demanding in terms of working memory resources, as the first representation required for the processing can be easily retrieved by the context. On the other hand, when negative sentences are presented in unsupportive contexts (e.g., true negative condition), working memory resources are overloaded by the necessity to create and compare two different mental representations. This working memory taxation has a negative impact on the computation, resulting in higher processing difficulties in true negatives than in false negative sentences.

Concluding remarks

The Two-Step Simulation Hypothesis discussed in this section can explain the higher processing difficulties reported with negative sentences. Significantly, this model also predicts the interaction between negation and sentence truth-value in sentence-picture verification tasks: response latencies are faster when the picture matches the negated state of affairs. Furthermore, it is worth nothing that the Two-Step Simulation Hypothesis takes into account the role of the context in the processing: longer reaction times in the true negative condition are due to the lack of a supportive context, which does not provide the comprehender with any hints for the simulation of the negated state of affairs. Nevertheless, this model considers the processing of negative sentences inherently more complex and demanding than that of affirmative sentences, as it requires the construction of one more mental simulation compared to the corresponding affirmative[40]. Supportive pragmatic contexts have a facilitating effect on a process which is however more difficult compared to that of affirmatives: even when a pragmatically felicitous context is provided (i.e., in the false negative condition), negative sentences still display longer reaction times and a lower accuracy in sentence picture verification tasks. Therefore, according to the Two-Step Simulation Hypothesis, context information can differently affect the processing of negation, which is nevertheless more demanding due to the nature of the mental simulations involved in the

[40] To the best of the author's knowledge, current experimental research on the Two-Step Simulation Hypothesis has not yet investigated the processing of negative sentences containing modal verbs, past tenses or other semantic operators.

comprehension process.

2.2.2 Incremental models of negation processing

Incremental models assume that, exactly as it happens for non-negative words, the semantic contribution of negation is immediately incorporated into the interpretative process. In this respect, negative sentence processing would hence resemble that of affirmatives, with no extra time nor effort required for the computation. In the previous section, we have seen that non-incremental models assume that the interpretation of negation occurs only after the consideration of the negated meaning of the sentence[41]: in particular, the Two-Step Simulation Hypothesis (Kaup et al. 2007) claims that the representations of both the negated and the actual state of affairs are momentarily maintained in different representational systems, which have some degree of interaction to allow the comparison and evaluation of the two mental simulations. Instead, incremental models consider the interpretation process do be more rigid and straightforward. Negation is integrated right away into sentence meaning, and the information occurring under its scope is rapidly suppressed as soon as encountered rather than maintained for a later comparison.

Two main incremental models of sentence comprehension can be distinguished, based on which theoretical aspect they consider as the main feature of negation. Pragmatic accounts (§2.2.2.1) focus on the high pragmatic sensitivity of negation, claiming that processing difficulty generally associated with negation must be attributed to pragmatic factors. Suppressive-like accounts (§2.2.2.2), instead, put emphasis on the inhibitory power of negative markers.

2.2.2.1 Pragmatic accounts

As we said, negation is generally used in natural languages to correct an asserted presupposition or a previous expectation which has been established in the communicative context (Wason 1965; Givòn 1978; Horn 1989). Quite the opposite, in experimental protocols such as sentence-picture verification tasks, negative sentences are often employed in isolation and without a supportive discourse context: as a consequence, their use is not pragmatically justified, and negative sentences are perceived by the comprehender as inappropriate, overloading the processing costs. As we will see throughout this section, a large number of studies have shown that the higher processing cost reported for negative sentences can be

[41] The mental simulation of the negated state of affairs can be propositional (as in propositional theories, §2.2.1.1), referential (as in representational models, §2.2.1.2) or experiential (as in experiential-simulation models, §2.2.1.3) in nature depending on the model of language comprehension adopted.

significantly reduced when they are uttered in pragmatically felicitous contexts. This theoretical claim is based on Wason's (1965) notion of plausible denial. Moving from the assumption that the use of negative sentences is appropriate when there is a previous expectation to be denied, and, significantly, this expectation is plausible, Wason assumed that negation can be used felicitously in order to describe a contrasting item against a class of homogeneous items, rather than to describe a situation in which a specific item is consistent with all the others. Consider for instance the following negative sentences:

(28) The whale is not a fish
(29) The whale is not a bird

Although both of them are true, Wason (1965) noticed that (29) was perceived by comprehenders as more unusual than (28), and, significantly, it took longer to be processed. The author accounted for these behavioural data by pointing out a crucial difference between the two types of negatives. The former can be considered a plausible negative statement, as it is likely to assume that a listener might think that whales are fish. Instead, the latter is perceived as extremely incongruous, as no one, given their encyclopaedic world knowledge, would assume the whale being a bird. Hence, only (28) is uttered in a supportive context: there is an expectation to be denied (i.e., the whale being a fish), which is due to the item exceptionality in comparison with other similar items (i.e., despite being a sea creature, the whale is a mammal). On the contrary, in (29) there is not an expectation for the whale being a bird, and this means that the whale cannot be considered as an incongruous element within the broader class of elements constituted by birds.

Wason (1965) further investigated this hypothesis of plausible denial by presenting participants with a picture of eight circles, numbered consecutively from one to eight, consisting of seven similar items (e.g., seven red circles), and one dissimilar item (e.g., one blue circle). Then, they were asked to complete affirmative and negative statements concerning the properties of the circles of the type of *Circle 7 is/is not*: affirmative and negative sentences were about the colour of either the dissimilar item (e.g., the blue circle) or that of a similar one (e.g., one of the red circles). The results showed that completing negative statements took generally longer than completing the affirmative ones. However, this delay significantly decreased when negative sentences were about the circle with the dissimilar colour (30) than when they described one of the similar items (31).

(30) Circle 7 is not red
(31) Circle 4 is not blue

This pattern of results confirms what assumed by the notion of plausible denial: negative sentences are uttered felicitously when they are used in order to underline a deviation from a prior statement or expectation established in the discourse context. As a matter of fact, when presented with a picture consisting of seven out of eight red figures, participants are likely to consider the only blue figure as an exception to a consistent colour pattern: this makes plausible the use of negation in (30) to describe a dissimilar item which deviates from the expectation established in the visual context. Conversely, in the same context, there is no reason to expect a red circle to be blue instead: hence, in this situation, the use of negation in (31) is perceived as unusual as it is pragmatically infelicitous.

Significantly, young children seem already able to perceive the pragmatic aspects underlying the proper use of negative statements. De Villiers and Flusberg (1975) investigated the comprehension of negative statements by two children aged three and four years: presented with pictures similar to those adopted by Wason (1965), they were asked to judge whether the related sentences were correct. Interestingly, children displayed a similar behaviour to that of adults, since they took longer and made more errors in judging the correctness of implausible negative sentences in comparison with that of the plausible ones.

To summarize, Wason claimed that the higher processing difficulty generally associated with negative sentences is a consequence of certain experimental designs, in which negative sentences are uttered in isolation and in unsupportive pragmatic contexts, hence deviating from their common use in everyday communication. Consider, for instance, Lüdtke et al. (2008)'s sentence picture verification set-up. In the true negative condition, participants were presented with the sentence *In front of the tower there is not a lion* and the picture of a ghost in front of the tower. Despite being both grammatically correct and true, the negative sentence is presented in a pragmatically infelicitous context. In a normal conversation, it is unlikely that this sentence would be uttered unless there were good reasons to suppose that the lion might have been there: however, the presence of a lion in discourse context was neither introduced by a previous statement (e.g., "Mary thought that there was a lion in front of the tower") nor related to what depicted in the picture. Therefore, the sentence turned out to be infelicitous and sounded inappropriate to the comprehender, who had to reconstruct a supportive context on their own in order to understand it (e.g., a lion was supposed to be in front of the tower, but it is not the case because there is a ghost instead). This context accommodation results in a more demanding processing for true negative sentences. On the other hand, in the false negative condition, the use of the negative sentence *In front of the tower there is no ghost* is pragmatically justified by the visual scenario: the picture of a ghost in front of a tower makes this statement, even if false, plausible, as it is consistent with the discourse context.

A large number of studies has provided evidence in favour of this pragmatic view of negation, showing that the higher processing difficulty found in negative sentences in comparison with corresponding affirmatives significantly decreases, or even disappears, when they are uttered in pragmatically felicitous contexts

(Nieuwland and Kuperberg 2008; Dale and Duran 2011, among others). These findings have led to the elaboration of different accounts of negation processing, which attribute the higher processing costs for negative sentences *entirely* to the fact that in many experimental paradigms they are presented without a supportive pragmatic context.

This represents the main difference with non-incremental models of negation processing: although both these views consider a pragmatic felicitous context to have a facilitating effect on the processing, they nevertheless make very different assumptions concerning the nature of the processing itself. Non-incremental models assume that negative sentence processing is inherently more demanding compared to that of corresponding affirmatives because it involves more complex and partially different cognitive representations. Instead, pragmatic accounts do not consider the processing of negative sentences intrinsically different from that of affirmatives, but, rather, it would be the absence of an adequate pragmatic context that makes an otherwise simple process more demanding.

Negation processing is context-dependent

Glenberg and Robertson (1999) investigated the reading time for affirmative and negative sentences presented in supportive and unsupportive discourse contexts. Participants were presented with short texts in which the final sentence was either positive (e.g., *The couch was black*) or negative (e.g., *The couch was not black*). In the supportive condition, the text put emphasis on the attribute referred to in the test sentence (32); on the other hand, in the unsupportive condition (33), the text was not informative to this respect.

(32) She wasn't sure if a darkly coloured couch would look the best or a lighter colour. The couch was / was not black

(33) She wasn't sure what kind of material she wanted the couch to be made of. The couch was / was not black.

Results showed that negative sentences took longer to be processed than the corresponding affirmative ones only in pragmatically unsupportive contexts. Significantly, when the context was adequately informative the processing times for both the polarity conditions did not differ. These findings confirm that the processing difficulty for negative sentences is significantly related to the pragmatic appropriateness of the context in which these sentences occur. Moreover, they also suggest that negation processing seems to be more context-dependent than that of affirmation.

Lüdtke and Kaup (2006) further investigated the role of an adequate context for the processing of negative sentences in two experiments that confirmed Glenberg and Robertson's (1999) observations. In the first experiment, participants were asked to read affirmative and negative sentences describing the property of a certain entity (e.g., *The water was / was not warm*), which had been always introduced in a previous text. By doing so, a pragmatic felicitous context was provided for all the test sentences. The linguistic context was manipulated so that the target sentence could be either mentioned (34) or not (35) in the previous text. Moreover, when mentioned, the statement could be presented as the only possibility (34) or as one of two alternatives (36).

(34) She wondered whether the water would be warm. The water was / was not warm.
(35) She wondered what the water would be like. The water was / was not warm.
(36) She wondered whether the water would be warm or cold. The water was / was not warm.

The results showed that negative sentences were positively affected by the context manipulation, with shorter reading times in the conditions in which the negated proposition had been explicitly mentioned in the previous text, either as the only possibility or as one of the two (34;36). Conversely, the reading times for affirmative sentences were not affected by context manipulations. In the second experiment, the linguistic context was manipulated so that the test sentences were never explicitly mentioned. Participants were presented with short stories which did not include the test sentences: the relevant information about the target entity (e.g., *A boy's t-shirt*) could only be inferred, more or less strongly, by the previous stories provided as contextual background (e.g., a boy's t-shirt's dirtiness after having played outside). This inference was then corrected by means of affirmative (e.g., *The t-shirt was clean*) or negative (e.g., *The t-shirt was not dirty*) test sentences. Results showed that negative sentences required more processing time than their affirmative counterparts when the context did not strongly infer the negated proposition. Instead, when the context did strongly suggest it, no significant difference in reading times was found between negative and corresponding affirmative sentences.

All in all, the results of these two experiments confirmed that negative sentences are processed more felicitously in contexts in which the negated proposition is either explicitly mentioned (as in Experiment 1) or it is highly inferable in the discourse context (as in Experiment 2). Therefore, these findings provide further confirmation that contextual pragmatic factors are linked to the processing difficulty generally associated with negative statements: a prior expectation (either inferred or explicitly mentioned) to be denied makes negative sentences pragmatically more adequate and hence more easily interpretable.[42]

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[42] It is worth nothing, however, that the results by Glenberg & Robertson (1999) and those by Lüdtke & Kaup (2006) have been taken as evidence for different models of negation processing: the former for a pragmatic account of negation processing, whereas the latter for the Two-Step Simulation Hypothesis. Despite agreeing on the positive role of a felicitous pragmatic context on the processing

Glenberg and Robertson (1999) considered negation to be intrinsically contextual. Nevertheless, other supporters of pragmatic accounts assume that the processing of negative sentences can imply different cognitive processes depending on whether they are uttered in supportive or unsupportive contexts. Dale and Duran (2011) observed that, even in everyday communication, negation is not always used in appropriate situations, and it must be interpreted in pragmatically infelicitous contexts. Moving from this observation, they conducted three action-dynamic experiments, in which the mouse-tracking trajectories were analysed during the evaluation of positive and negative sentences presented in different types of contexts. Participants were asked to silently read affirmative (37) and negative (38) sentences which could be either true or false on the basis of the comprehender's world knowledge. Then, they had to judge the truthfulness of the sentences by clicking with the mouse on the buttons *true/false* shown on the screen. Within the action-dynamic paradigm, mouse-tracking trajectories towards the chosen button are generally considered as index of the cognitive cost of a specific task: the number of deviations and the different patterns of acceleration/deceleration in the trajectories were analysed, as they are considered to be strongly correlated with processing difficulty.

(37) a. Elephants are large (true affirmative)
b. Elephants are small (false affirmative)
(38) a. Elephants are not large (false negative)
b. Elephants are not small[43] (true negative)

The appropriateness of the linguistic context was manipulated across the three experimental tasks. In the first experiment, the test sentences were presented in isolation, and the results indicated that, as expected, a higher discreteness in movements and deviations of the mouse trajectory was found with negative sentences. In the second experiment, the very same test sentences used in Experiment 1 were inserted in a more plausible context by introducing a preliminary question:

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of negative sentences, the authors make very different assumptions on the nature of negative sentences and on aspects of the processing.

[43] It is worth noting that *small* has itself a negative connotation, which might have further slowed down the sentence interpretation process in unsupportive pragmatic contexts (Experiment 1-2). Consider for example the following sentences:

a) Both Minnie and Mickey Mouse are small, but Mickey is still taller than Minnie

b) Both John and Bill are huge and very tall, #but John is still smaller than Bill

(39) You want to lift an elephant? Elephants are not small!

Interestingly, despite the simple plausible context provided, the same pattern of results of the first experiment was found, with an increased discreteness in mouse trajectories for negative sentences compared to the corresponding affirmative sentences, indicating that the former were still perceived, to some extent, as pragmatically infelicitous. Moreover, the results also confirmed the negation-by-truth-value effect found in classical sentence picture verification studies (e.g., Wason 1961 among others), with true negative sentences showing the highest number of mouse trajectories and speed alternation. In the third and last experiment, test sentences were presented in a strongly supportive pragmatic context, which further licensed the pragmatic felicity conditions for negative sentences: both the preliminary question and the test sentence were presented to participants as adult statements used to correct a child's assumption. The results indicated a significant decrease of the discreteness of mouse trajectories and speed alternation for negative sentences in comparison with the first two experiments, demonstrating that richer contextual and pragmatic information has a facilitating effect for the processing of negative sentences. Given this pattern of findings, the authors proposed that the processing of negation has a dynamic structure that changes contextually. Depending on the context in which negative sentences are uttered, negation processing can involve different cognitive aspects. When negative statements are presented in unsupportive contexts such as in Experiment 1 and 2, negation processing is more discrete, or, in other words, non-incremental: the processing of negative sentences is more demanding than that of affirmative ones because the comprehenders have to reconstruct a supportive discourse context for sentence interpretation, creating the corresponding positive assumption denied by the negative statement. On the contrary, in a stronger and more supportive context such as in Experiment 3, negation processing is facilitated by these pragmatic discourse factors: as demonstrated by behavioural data, negation is integrated more smoothly and immediately, or incrementally, into sentence comprehension.

Nieuwland and Kuperberg (2008) drew similar conclusions after investigating the interpretation of affirmative and negative sentences in pragmatically felicitous and infelicitous contexts. They presented participants with affirmative and negative sentences which could be either true or false. Both for pragmatically felicitous and infelicitous sentences, the linguistic context consisted in the very same single statement, which was relevant to the meaning of the former but completely unrelated to that of the latter (see Figure 1.7 for an example of stimuli for pragmatically licensed and unlicensed sentences). Participants were only asked to read the test sentences without having to judge their truthfulness. ERP responses were measured during the reading task[44].

Condition	Example sentence
Pragmatically licensed negation	
True-affirmative	With proper equipment, scuba-diving is very safe and often good fun.
True-negated	With proper equipment, scuba-diving isn't very dangerous and often good fun.
False-affirmative	With proper equipment, scuba-diving is very dangerous and often good fun.
False-negated	With proper equipment, scuba-diving isn't very safe and often good fun.
Pragmatically unlicensed negation	
True-affirmative	Bulletproof vests are very safe and used worldwide for security.
True-negated	Bulletproof vests aren't very dangerous and used worldwide for security.
False-affirmative	Bulletproof vests are very dangerous and used worldwide for security.
False-negated	Bulletproof vests aren't very safe and used worldwide for security.

Figure 1.7. Examples of stimuli in Nieuwland and Kuperberg (2008) for pragmatically licensed and unlicensed sentences

Results showed that, in pragmatically felicitous contexts, larger N400 amplitudes were elicited by false words in both affirmative and negative sentences, reflecting the sentence truth-value. Conversely, in pragmatically unsupportive contexts, larger N400 amplitudes were found not only after false words in both polarity conditions but also after true words in negative sentences. As discussed in §2.2.1.3, Nieuwland and Kuperberg (2008) strongly criticized Lüdtke et al. (2008)'s experimental design that was lacking a proper supportive context in all the experimental conditions, claiming that the higher N400 modulations associated with negative sentence interpretation could be due to this absence of a proper discourse context. The results of Nieuwland and Kuperberg (2008)'s study clearly speak in favour of this assumption. The reported findings suggest that the processing of negation is not necessarily more difficult than that of affirmation, but only more sensitive to pragmatic factors: when negative sentences are uttered in a pragmatically felicitous context, negation is directly integrated into sentence comprehension. However, according to the authors, it cannot be excluded that negative sentences are processed non-incrementally under unsupportive contextual circumstances.

Nonetheless, some noticeable methodological criticisms can also be made towards Nieuwland and Kuperberg (2008)'s ERP study. In order to avoid pragmatic infelicity, the authors provided a preliminary statement (e.g., *With proper equipment* in pragmatically licensed condition), which, however, constituted a strong bias in support of true sentences: as a consequence, false sentences, regardless of their polarity, were perceived by comprehenders as extremely unexpected compared to their true counterpart. This was demonstrated by a rating

[44] Event-related potentials were recorded from the critical word onset (underlined in Fig. 1.7), which determined the truth-value of the test sentence.

test, in which a different group of participants, who did not take part in the ERP experiment, were asked to rate the naturalness of the test sentences with a score from 1 (i.e., unnatural) to 5 (i.e., natural). The results clearly indicated that, whereas true affirmative and negative sentences were perceived as quite natural (± 4 average score), the corresponding false sentences were instead perceived as extremely unnatural (± 1.37 average score). In addition, the truth-value of the test sentences could be immediately determined on the basis of the comprehender's world knowledge. This caused a temporal overlap between those cognitive processes related to the computation of the linguistic stimuli and those involved in the sentence-verification, and, therefore, it has not been possible to adequately distinguish them.

Similar results were also reported by Staab et al. (2008), who recorded event-related potentials during the verification of affirmative and negative sentences (e.g., *He bought / did not buy cookies*). Participants were asked to read short narratives describing choices made by different people, and to decide whether the final sentence of the story was consistent with the information previously provided. For instance, the true negative condition consisted in the following scenario:

(40) During his long flight Joe needed a snack. The flight attendant could only offer him pretzels and cookies. Joe wanted something salty, so he didn't buy cookies.

In line with Nieuwland and Kuperberg (2008), the event-related potential analysis showed that larger N400 amplitudes were elicited in false sentences, independently from their polarity, indicating that when negative statements are provided in supportive pragmatic contexts, the N400 component is mainly affected by sentence truth-value. Furthermore, Ferguson et al. (2008) provided evidence that, while negation is processed very quickly, and it is immediately integrated into sentence meaning when presented in supportive pragmatic contexts, its interpretation is slowed down when used in unsupportive situations, as it involves non-automatic memory-based cognitive processes. The authors conducted an eye-tracking experiment to investigate the processing of sentences in real-world congruent and incongruent contexts. In the former, the introductory text provided to participants was consistent with their general world-knowledge (e.g., *If cats are hungry*); in the latter, instead, the information provided in the text contradicted comprehender's knowledge of the world (e.g., *If cats were not carnivores*). In both cases, the short text was followed by a sentence which could be either congruent or incongruent with the context provided: sentence in/congruency with respect to the previous context was determined by the critical word underlined in (41a-d). To exemplify, the experimental design consisted in the following four conditions:

(41) a. If cats are hungry, they usually pester their owners until they get fed. Families could feed their cat a bowl of <u>fish</u> and listen to it purr happily. (real-world consistent sentences)
b. If cats are hungry, they usually pester their owners until they get fed. Families could feed their cat a bowl of <u>carrots</u> and listen to it purr happily. (real-world inconsistent sentences)
c. If cats were not carnivores, they would be cheaper for owners to look after. Families could feed their cat a bowl of <u>carrots</u> and listen to it purr happily. (negated-world consistent sentences)
d. If cats were not carnivores, they would be cheaper for owners to look after. Families could feed their cat a bowl of <u>fish</u> and listen to it purr happily. (negated-world inconsistent sentences)

From the eye-movement analysis it clearly emerged that, in the real-world condition, sentences presented in incongruent contexts displayed longer reading times, longer fixations and a higher number of regressions towards the critical word in comparison to the sentences presented in congruent contexts. Conversely, in the negated-world condition, the integration of the critical word in the sentence comprehension resulted significantly delayed. According to the authors, this would reflect the comprehender's need to adjust the information provided by the experimental context with their encyclopaedic knowledge, similarly to what happens when negative sentences are presented in isolation and the comprehender has to compensate for the lack of contextual information. As a consequence, this context accommodation forces the comprehender to overload working memory resources with extra effort, and, as predicted by Deutsch et al. (2006), it results in a delayed detection of sentence inconsistency in the negated-world condition.

Taken together, the reported findings confirm Wason's (1965) notion of plausible denial, strongly suggesting that negation processing is highly sensitive to contextual aspects. The absence of a felicitous context of utterance would hence be responsible for the increased difficulty generally associated with negation processing. When presented in pragmatically felicitous contexts, negation is incrementally incorporated into sentence meaning, and its comprehension does not seem to require more effort compared to that of affirmative sentences. Instead, when uttered in isolation or in unsupportive discourse contexts, it is not excluded that negation can receive a two-stage based interpretation due to the need for the comprehender to first accommodate the discourse situational context.

The QUD accommodation account

The dynamic pragmatic account proposed by Tian, Breheny, and Ferguson (2010) is an alternative incremental model of sentence processing which provides an explicit explanation of why, under certain circumstances, the negated state of affairs is considered to be represented during negative sentence comprehension.

Dynamic accounts of language comprehension consider the relevance of a statement in terms of a set of salient Questions Under Discussion (QUDs), which can be defined as questions which collocate the utterance within a supportive situational context (Ginzburg 2012; Roberts 2012). In everyday communication, each sentence addresses, though often implicitly, a QUD: for instance, the sentence *The bird is in the air* leads the comprehender to the projection of the following QUD *What is in the air*? The linguistic form of an utterance contains cues for the underlying QUD (e.g., prosodic features): if the context information is lacking, the comprehender can rely on these linguistic cues to retrieve the most plausible QUD addressed by the given sentence. Tian et al. (2010) considered negation as a strong cue for QUDs: crucially, when no other contextual cues are provided, the most plausible QUD for a negative sentence such as *The bird is not in the air* consists in the question of whether the negative sentence's positive counterpart is true (i.e., *Is the bird in the air?*). This positive QUD is extremely prominent because it reflects the most frequent use of negation in natural languages, that is, rejecting a previous assumption or positive presupposition (Wason 1959, 1961; Givòn 1978; Horn 1989).

According to the authors, when a negative sentence is uttered in isolation or in an unsupportive context, its comprehension triggers the accommodation of the positive QUD in order to adjust the lacking presupposition that the negative sentence should address. The projection of this positive QUD explains why, in studies where negative sentences are presented in isolation, it has been found substantial evidence for a computational step involving the representation of the negated state of affairs. Therefore, the interpretation of infelicitous negative sentences would not rely on different cognitive processes with respect to that of pragmatically licensed sentences, but, rather, it would involve a positive QUD accommodation, which occurs incrementally with respect to the processing of the semantic meaning of the sentence itself, and burdens the comprehension process.

Tian et al. (2010) compared the interpretation of simple negative sentences (42) and cleft structures with embedded negative statements (43) presented in isolation. Differently from simple sentences, cleft structures are considered to be presupposition triggers. As said before, a simple negative sentence such as (42) elicits the positive presupposition that Jane should have cooked spaghetti: if the sentence is uttered out of an adequate context, it will be perceived as inappropriate, and, hence, the comprehender will have to accommodate the corresponding positive QUD. On the other hand, a cleft structure such as (43) conveys the implicit negative presupposition that someone did not cook spaghetti: even if presented out of any supportive context, (43) is perceived by the comprehender as pragmatically more appropriate than (42) because it licenses a negative QUD and, consequently, the processing is not taxed by the need to represent the corresponding positive assumption.

(42) Jane did not cook spaghetti (QUD *Did Jane cook spaghetti?*)
(43) It was Jane who did not cook spaghetti (QUD *Who did not cook spaghetti?*)

Similarly to Kaup et al. (2007), 250ms after reading the test sentences participants were presented with a picture matching either the actual sentence meaning (e.g., raw spaghetti), or the corresponding positive situation (e.g., cooked spaghetti). They had to decide whether the depicted entity (e.g., spaghetti) had been mentioned in the previous sentence. The results showed that after the presentation of simple negative sentences participants were faster in the recognition task if the picture was consistent with the corresponding positive situation (e.g., cooked spaghetti), indicating that negation had not been yet integrated into sentence meaning. Conversely, after the presentation of cleft structures, participants were faster in recognizing the picture consistent with the negative situation (e.g., raw spaghetti). The results confirmed the assumption made by the dynamic pragmatic account: the comprehension process of simple negative sentences presented in isolation is slowed down by the need to adjust the lacking contextual information by accommodating the corresponding positive QUD. On the other hand, the negative QUD triggered by the cleft sentences such as (43) has a significant facilitatory effect in the comprehension process of negation.

In a subsequent study, Tian et al. (2016) investigated at what point the meaning of negation is integrated in the comprehension process. Using a visual world eye-tracking set-up, they compared the time course of the processing of negative and affirmative sentences. Participants were auditorily presented with affirmative and negative statements, either in simple (44-45) or cleft structures (46-47), while looking at a visual scenario consisting of a picture matching the actual state of affairs (e.g., a crumpled t-shirt for (45-47)) and a picture matching the negated state of affairs (e.g., an ironed t-shirt for (44-46)).

(44) John has ironed his brother's shirt
(45) John has not ironed his brother's shirt
(46) It is John who has ironed his brother's shirt
(47) It is John who has not ironed his brother's shirt

The Two-Step Simulation Hypothesis makes similar predictions for the time course of the processing of simple and cleft negative sentences, both of which would be processed by first simulating the positive argument of negation (e.g., John has ironed the t-shirt). In terms of behavioural data it hence predicts: i) a delay in target identification for the negative form with respect to the corresponding affirmative, due to the two-stage based computation required for negative statements; ii) for negative sentences, independently of the linguistic form, an increase of initial fixations towards the picture matching the positive state of affairs (e.g., an ironed t-shirt), before the attentional shift towards the actual target (e.g., a crumpled t-shirt). On the contrary, the incremental QUD accommodation account assumes that the comprehender incrementally updates information about sentence meaning and QUD in parallel, and not in temporarily distinct processing stages. As shown in Tian et al. (2010), simple positive (44) and negative (45) sentences yield the same positive QUD *Has John ironed his brother t-shirt?* Hence, the authors predicted that with simple negative sentences such as (45) the comprehender will initially pay attention to both the picture matching the negative meaning (e.g., a crumpled t-shirt) and the picture representing the positive situation (an ironed t-shirt) as they have to accommodate the positive QUD with the actual sentence meaning. Instead, a strong early bias towards the positive picture (e.g., an ironed t-shirt) is predicted for the corresponding simple affirmative sentence (44), since both the content and the QUD yield the same positive polarity. Given that for both affirmative and negative cleft structures the likely QUD has the same polarity of the corresponding sentence content (e.g., a crumpled t-shirt for (47), and an ironed t-shirt for (46)), the authors predicted no processing delay for negative cleft sentences in comparison with the corresponding affirmatives.

Results showed a processing difference between simple but not cleft sentences. With simple negative sentences, comprehenders initially paid attention to both the picture of the negated situation and the picture consistent with the actual sentence meaning, and they shifted their attention towards the actual target within 900ms from the verb offset. Instead, with simple affirmative sentences, comprehenders focused on the target picture immediately after the verb offset: the delay in the simple negative condition suggests that the representation of the positive counterpart is initially activated when processing simple negative sentences uttered in isolation. Nevertheless, participants initially paid similar attention to both the pictures when presented with cleft structures, independently from sentence polarity.

These findings further corroborated Tian et al.'s (2010; 2016) hypothesis that the processing delay reported for simple negative sentences is not evidence for a first stage of negation processing, but, rather, it is due to the QUD accommodation. When uttered in isolation, the most plausible QUD for simple negative sentences is positive, and, hence it is incongruent with negative sentence meaning: this QUD accommodation requires the representation of the content consistent with the corresponding positive situation, resulting in a more demanding processing. On the other hand, the negative cleft structure has a prominent negative QUD: the projection of this QUD matches the representation of sentence meaning. The same holds for positive cleft sentences, where both the QUD and the sentence meaning yield a positive polarity. Therefore, in cleft structures, the time course of the processing of negative sentences is no more delayed than that of affirmatives, as no QUD accommodation with sentence meaning is required.

According to Tian and colleagues, these results are incompatible with non-incremental accounts such as the Two-Step Simulation Hypothesis. First of all, given that both simple and cleft negative sentences provide the same semantic information, the Two-Step Simulation Hypothesis would predict a delay in target identification for both these structures with respect to the corresponding affirmative form: instead, the results reported this delayed pattern only among simple sentence structures. In addition, the Two-Step Simulation Hypothesis considers the simulation of the positive state of affairs as a temporarily distinct stage in negation processing, occurring before the representation of the actual sentence meaning. Once again, the results of the present study go in the opposite direction: in negative sentences, before focussing on the representation of the actual state of affairs, comprehenders initially paid equal attention to both the pictures presented in the visual scenario, and not only to the picture matching the corresponding positive situation. According to the authors, this strongly suggests that the simulation of the positive counterpart cannot be considered a discrete step of negation processing, but rather it occurs in parallel, and hence incrementally, with the representation of sentence meaning. Finally, while non-incremental accounts assume that negation is integrated at a later stage into sentence meaning, the results for cleft structures indicate that negation can be incorporated incrementally, as occurs for the other linguistic elements.

To summarize, the QUD accommodation account proposed by Tian and colleagues (2010;2016) assumes that when negative sentences are presented in isolation or in unsupportive contexts, comprehenders do not just process the semantic meaning of the sentence, but they also accommodate a likely QUD consisting in the representation of the corresponding positive state of affairs. This would explain why classical studies (in which negative sentences are presented in isolation) often report evidence of a mental representation of the positive counterpart as first stage of negation processing. Nevertheless, according to the pragmatic account proposed by Tian et al. (2010; 2016), the activation of the corresponding positive representation does not qualify as a temporarily distinct processing step which precedes the simulation of the actual situation: rather, this QUD accommodation occurs incrementally during the processing of sentence meaning.

Consequently, the pragmatic QUD accommodation account completely rejects a non-incremental view of sentence processing. Moreover, it also significantly differs from the other pragmatic accounts discussed in the previous section: while the latter do not exclude the possibility that negative sentences undergo a two-stage based interpretation in pragmatic infelicitous contexts, under no circumstances the former considers negation processing as involving temporarily different computational stages.

2.2.2.2 Suppressive accounts

Among incremental models of negation processing, suppression-like accounts put particular emphasis on the inhibitory power of negation. Under this view, the key feature of sentential negation consists in reducing the later accessibility of its argument during the early stages of sentence comprehension. Although there is substantial evidence indicating that negation significantly reduces the accessibility of the information provided under its scope (MacDonald and Just 1989; Kaup et al. 1997; Hasson and Glucksberg 2006; Giora et al. 2005, 2007; Ferguson et al. 2008; Mayo et al. 2014; Orenes et al. 2014), there is no agreement yet on whether this inhibition is mandatory and when it occurs during the sentence comprehension process.

The *narrow-view* account (Carpenter and Just 1975; Evans and Over 2004) assumes that the suppression of the information under the scope of negation automatically occurs across all the discourse contexts. However, experimental findings have demonstrated that the context of utterance can strongly influence this inhibition (among others, see below Giora et al. 2007). According to the so-called *retention hypothesis* (Giora et al. 2004; 2007), the suppression of the argument of negation is functional to contextual considerations. If the negated information is not useful for sentence interpretation and discourse coherence purposes, its accessibility is significantly reduced. Instead, when the concept under the scope of negation is to some extent relevant for the interpretation process, it is retained and receives a weaker interpretation, which nonetheless resembles the original positive concept (Giora 2006; Giora et al. 2005).

Paradis and Willners (2006) presented their participants with affirmative and negative sentences including scalar adjectives (e.g., *The road along the coast is / is not narrow*). The task consisted in indicating the position of a target noun (e.g. road) on a scale ranging from two opposite points (e.g., narrow and wide). Results showed that target nouns were often assigned with extreme scalar position when presented in affirmative sentences, while the very same target nouns were assigned with intermediate positions on the scale when the statement contained negation. This suggests that the concept under the scope of negation is not completely inhibited but rather mitigated: since the concept of *not narrow* was interpreted as closer to the concept of *less than narrow* than to that of *wide*, some abstract properties of the negated concept seems to be retained during negative sentence processing[45].

Giora et al. (2007) conducted a series of experiments to investigate how contextual aspects can affect the inhibitory effect of negation. In a self-paced word-by-word reading task, participants were presented with the same negative metaphors (e.g., *The train was no rocket*) employed by Hasson and Glucksberg

[45] Note, however, that the use of the expression *not narrow* in the target sentence already implies that the road is not wide either, otherwise the term *wide* would have been more appropriate to use.

(2006). The test sentences were followed by either a consistent (48) or inconsistent (49) assertion. Both these strings included the same target word (e.g., *fast*) in the late discourse context, which was related to the affirmative meaning of the negated metaphor (e.g., *no rocket*). Participants were asked to read the sentences at their own natural pace.

(48) The train was no rocket. The trip to the city was fast though.
(49) The train was no rocket. The old man in the film spoke fast.

Results showed that the target words in the coherent context were read faster than the very same target words in the incoherent ones. This finding suggests that late contextual information can influence a potential suppression of the negated information. With a consistent continuation, the negated concept conveyed by the metaphorical expression (e.g., being fast) was not inhibited, but, rather, it primed the interpretation of the following sentence even when this was presented with a one second delay. On the other hand, when negative metaphors had an inconsistent continuation, the negated concept had no facilitating effect on the processing of the following sentence, suggesting that the suppression of the negated concept has been fostered by the irrelevant late discourse context. The effect of preceding supportive context on the retention of information with the scope of negation was investigated in a second experiment. Participants were asked to read short texts consisting of a negated concept (e.g., being wealthy) that was relevant with respect to preceding supportive information (e.g., millionaires).

(50) I live in the neighbourhood of millionaires who like only their own kind. Nonetheless on Saturday night, I also invited to the party at my place a woman who is not wealthy.

After reading, participants were shown a letter string that could consist in either nonwords or real words. In turn, the latter could be either related (e.g., rich) or not (e.g., quick) to the negated concept. The letter string was displayed either 100ms or 750ms after the offset of the target sentence. Participants had to decide whether the probe element was a real word or not. Results showed that in the 100ms delay condition no significant difference was found between response time to related (e.g., *rich* for *wealthy*) and unrelated probes (e.g., *quick* for *wealthy*). Instead, in the 750ms delay condition, response latencies for related probes were significantly faster than those for the unrelated ones. This indicates that, when preceded by relevant contextual information, the negated concept is maintained rather than suppressed up to 750ms following the sentence onset. The third and last experiment completely resembled Experiment 2 except for the time delay duration between the offset of the target sentence and the onset of the probe element, which has been extended to 1000ms. Results showed that, similarly to the 100ms delay condition in Experiment 2, response latencies to the related probes did not significantly differ from those to the unrelated probes. This clearly indicates that, even when supported by a prior coherent context, the concept under the scope of negation is no longer accessible 1000ms after the offset of the target sentence. Taken together, these findings indicate that the inhibitory effect of negation depends on global discourse considerations. Previous and late contextual information encourages the retainability of the concept occurring under the scope of negation. However, even when the absence of contextual cues prompts the inhibition of the negated information, the reduction of its accessibility does not occur during the early moments of sentence comprehension but, plausibly, between 750ms and 1000ms following its offset.

The results reported by Giora et al. (2007) are in line with a number of psycholinguistic findings showing that the accessibility of the information under the scope of negation is not inhibited during the early stages of sentence comprehension (Kaup and Zwaan 2003; Hasson and Glucksberg 2006; among others). For instance, Kaup et al. (2006) showed that after 750ms from the onset of the negative sentence the door is not open participants were faster in target recognition when presented with a picture matching the negated situation (e.g., an open door). After 1500ms the opposite pattern was found, with shorter response latencies when the picture matched the actual meaning of the sentence (e.g., a closed door). This is strong evidence that the meaning of the concept under negation is suppressed between 750ms and 1500ms after the sentence onset in favour of the activation of the alternative meaning (§2.2.1.3 for further details on the study). The authors interpreted these results as evidence for the Two-Step Simulation Hypothesis (§2.2.1.3). While Giora and colleagues (2005; 2007) assume that the inhibitory effect of negation is primarily affected by the contextual information provided, it is worth nothing that a non-incremental view of negation processing is not incompatible with the suppressive nature of negation: the late inhibition of the negated meaning might correspond to the second stage of sentence comprehension, during which the simulation of the positive state of affairs is rejected and negation is integrated into sentence meaning.

Interestingly, a number of studies have shown that the suppression of the negated concept is also affected by the types of predicates and terms involved. Mayo et al. (2004) claimed that the availability of an antonymic concept has a facilitating effect on the suppression of a negated term. In their study, they presented participants with a description of a person expressed as an affirmation or negation (e.g., Tom is / is not a tidy person), followed by a probe sentence which could be congruent (51), incongruent (52) with the previous description, or completely unrelated (53). The task was to determine whether the probe sentence was coherent with the description.

(51) Tom is not a tidy person. Tom forgets where he left his car keys. (congruent)

(52) Tom is not a tidy person. Tom's clothes are folded neatly in his closet. (incongruent)
(53) Tom is not a tidy person. Tom likes to have long conversations on the phone. (not related)

Results showed that, after reading the sentence *Tom is not a tidy person*, comprehenders were faster in evaluating a description congruent with the complementary meaning of the negative concept (e.g., *not tidy* is compatible with *messy* in (51)) rather than incongruent descriptions compatible with the concept under the scope of negation (52). Hence, this suggests that the meaning of the bipolar negated term is suppressed and comprehenders activate instead its antonymic meaning. On the other hand, when the negated term was unipolar (i.e., with no direct antonym such as *adventurous*), comprehenders were faster in the evaluation of the description compatible with the positive argument of negation (54), and hence incongruent with the negative sentence meaning rather than in the evaluation of the description congruent with the actual meaning of the negative sentence (55).

(54) Roy is not an adventurous person. Roy loves to travel to distant places. (incongruent)
(55) Roy is not an adventurous person. Roy is stressed by any change in his life. (congruent)

Mayo and colleagues (2004) accounted for these findings assuming that the inhibitory effect of negation is significantly affected by the nature of the information under its scope. The availability of a complementary term providing an alternative along a scalar dimension prompts the suppression of the negated meaning, which, instead, is retained when the antonymic term is vacant. Similar findings have been reported by studies conducting within the visual world paradigm[46]. In Orenes et al. (2014) participants were auditorily presented with a sentence describing either a binary (56) or multiple (57) context. Then, they listened to an affirmative or negative sentence indicating the property of the target entity (e.g., *The figure is/is not red*). In the meantime, four figures of different colours were displayed on the screen.

(56) The figure could be red or blue. The figure is / is not red.
(57) The figure could be red, blue, green or yellow. The figure is / is not red.

Independently of the discourse context provided, eye movements data showed an increase of fixations on the figure with the mentioned colour (e.g., red) for

[46] The study by Orenes et al. (2014) and, more in general, the Visual World Paradigm will be discussed in detail in chapter 3.

affirmative sentences. On the contrary, a different looking pattern behaviour was found for negative sentences between contexts. In the multiple context (57), participants consistently fixated the figure with the mentioned colour (e.g., red) from 400ms after the sentence offset. In the binary context (56), instead, the participants' looking pattern behaviour indicated an increase of fixations on the figure with the alternative colour (e.g., blue) from 1340ms after the sentence offset. This suggested that the inhibition of the information under the scope of negation does not occur by default in all contexts: nevertheless, when a complementary concept is available as in the case of binary contexts, the meaning of the negated term is suppressed.

Neural inhibition of motor brain activity

According to the Embodiment Cognition Theory, the comprehension of a linguistic sentence activates the same neural structures enabled by the effective execution of the action described in the sentence itself. In recent years, a growing number of neuro-imaging studies investigated the involvement of different brain areas in language processing, providing important confirmation that specific sensorimotor neuronal systems are involved in language comprehension. As concerns the processing of sentential negation, embodiment cognition research provided substantial neurological evidence of the early suppressive effect of negation: specifically, a large number of studies employing different neuro-imaging techniques have shown that the presence of linguistic negation determines a reduced activation of those brain areas usually activated by the information occurring under its scope (Tettamanti et al. 2008; Tomasino et al. 2010; Liuzza et al. 2011; Alemanno et al. 2012; Bartoli et al. 2013; Foroni and Semin 2013). Moreover, the early occurrence of this suppressive effect, already within 500ms after stimuli onset, provides persuading evidence in favour of an incremental view of negative sentence processing.

Experimental evidence of an interaction between language comprehension and specific brain areas has been reported by Tettamanti and Buccino (2005), who conducted an fMRI[47] study to investigate different neuronal activations during the interpretation of action-related (58) and abstract sentences (59).

(58) Now I bite the apple

[47] Functional Magnetic Resonance Imaging (fMRI) measures brain activity by detecting changes in blood oxygenation and flow. This neuro-imaging technique is based on the evidence that when brain areas are activated, they consume more oxygen, with a consequently greater blood flood in the areas of interest.

(59) Now I appreciate the loyalty[48]

Results showed that different properties of the linguistic stimuli, such as the concreteness of the action described, result in different neural activations. Both types of stimuli enhanced left premotor cortex activity: however, while the interpretation of abstract sentences (59) involved only the activation of the posterior cingulate cortex, the entire left fronto-parieto-temporal system, including the inferior parietal lobule and the posterior temporal cortex were activated during the processing of action-related statements (58). Significantly, these brain areas are respectively involved in the processing of abstract and concrete semantic properties.

In a follow-up study, Tettamanti et al. (2008) presented participants with the same abstract and action-related sentences proposed by Tettamanti and Buccino (2005) in affirmative and negative forms. Interestingly, results showed that the processing of negative sentences (e.g., *I don't bite/I don't appreciate*) caused a reduction of brain activities in comparison to the corresponding affirmatives (e.g., *I bite/I appreciate*). Both types of negative sentences determined a reduced activation of the pallidocortical areas, associated with a variety of functions including control of voluntary motor movements and emotion. Moreover, a hemodynamic flow reduction was found in the left fronto-parietal regions with action-related negative sentences, and in the posterior cingulate cortex with abstract negative ones.

The inhibitory effect of negation on specific brain areas has been subsequently investigated by a consistent number of neuro-imaging studies, which mainly focused on the processing of action-related verbs. Tomasino et al. (2010) investigated the different cortical activations during the comprehension of affirmative and negative imperative sentences. In their fMRI study, participants were asked to silently read hand action-related verbs (60) and non-existing verbs (61). The task consisted in judging whether the verb was a real word or not.

(60) Do write / Don't write
(61) Do gralp / Don't gralp

With action-related verbs, results showed a significant activation of the motor areas (i.e., primary motor and premotor cortex) during the processing of affirmative sentences (e.g., *Do write*), and a significant activation decrease of the same brain networks during the processing of the corresponding negative sentences (e.g., *Don't write*). In addition, behavioural results indicated a significant polarity effect, with longer response latencies during the lexical decision task for negative action-related imperatives in comparison with the corresponding affirmative structures. On the

[48] English translation of the original Italian sentences: (58) Ora mordo la mela; (59) Ora apprezzo la lealtà

other hand, while the processing of affirmative non-existing verbs (e.g., *Do gralp*) only occasionally elicited the activation of motor areas, the corresponding negative structures (e.g., *Don't gralp*) did not determine any cortical inhibition. Furthermore, the neuronal activity was not even influenced by sentence polarity. Taken together, these results are in line with previous findings by Tettamanti and colleagues (2005; 2008) in two respects. First, they suggest that linguistic properties differently affect neural activations during sentence processing. Second, neuro-imaging results strongly indicate that negation has an inhibitory effect on the activation of brain networks: this would consequently result in a reduced lexical accessibility of the information occurring under the scope of negation, as demonstrated, according to the authors, by the polarity effect found among action-related verbs. Liuzza et al. (2011) conducted a study similar to Tettamanti et al. (2008) employing the TMS[49] technique to measure the excitability of the motor system during sentence comprehension. Participants were asked to read action-related (62) and abstract sentences (63), either of positive or negative polarity.

(62) I do not squeeze / squeeze the lemon
(63) I do not remember / remember the past[50]

Results showed that, among affirmative sentences, the activation of sensorimotor brain areas was only reported while reading action-related sentences (e.g., *I squeeze the lemon*). However, this modulation has not been observed while reading the corresponding negative sentences (e.g., *I do not squeeze the lemon*). Similarly, in Alemanno et al. (2012)'s EEG study, participants were asked to silently read hand-action related (64) and abstract (65) Italian sentences, and to decide whether the mentioned verb was frequent or not in Italian.

(64) I do not write / write
(65) I do not think / think[51]

A significant mu rhythm desynchronization[52] over the left motor and premotor areas

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[49] Transcranial Magnetic Simulation (TSM) is a non-invasive procedure that uses magnetic fields to stimulate the activation of specific brain areas. By means of an electromagnetic coil connected to the scalp, short magnet pulses are administered to the patient, which stimulate the nerve cells in either specific or general parts of interest in the brain.

[50] English translation of the original Italian sentences: (62) Io non/spremo il limone; (63) Io non/ricordo il passato

[51] English translation of the original Italian sentences: (64) Io non/scrivo; (65) Io non/penso

[52] Mu waves (or rhythms) are synchronized patterns of electrophysiological activity involving a massive number of neurons in the brain areas devoted to the control of voluntary movement. These waves reflect the motor cortex activity in terms of desynchronization: when a person is carrying out a motor activity or even while she is observing another person performing physical actions, the mu waves are suppressed because a large number of neurons are firing simultaneously. Thus, a significant mu rhythm desynchronization indicates motor cortex area activity.

(usually involved in manual execution) was reported during reading of affirmative hand-action sentences (e.g., *I write*) but not during that of abstract sentences (e.g., *I think*). Moreover, for negative hand-action sentences, results showed a delayed mu ERD[53] and mu waves of larger amplitudes, indicating that the same cortical areas are activated less during the processing of negative sentences.

Papeo et al. (2012) employed chronometric TMS to investigate how negation affects the neural representation of a word meaning in terms of motor excitability and inhibition of specific brain networks. Participants were asked to read affirmative and negative statements denoting either manual actions (66) or psychological states (67).

(66) Now I write/ I do not write
(67) Now I wonder/ I do not wonder[54]

During the task, TMS measured the motor excitability (MEPs) at different points in time. Results showed larger MEP amplitudes with action-related verbs than with state verbs. While the processing of state verbs was not significantly affected by sentence polarity, MEP amplitudes for negated action verbs (e.g., *I do not write*) were lower than MEP amplitudes for the corresponding positive statement (e.g., *Now I write)*. Moreover, since these reduced amplitudes occurred only 250ms after the word onset, the presence of negation seemed to affect the computation of action-related verbs already during the earliest stages of sentence processing. All in all, these findings strongly indicate that the cortical representation of affirmative and negative action meanings are distinguishable as soon as semantic effects are observed in the brain. During the early moments of sentence comprehension negation modifies the neural representation of the argument under its scope by inhibiting the access to some neural information related to the positive meaning of the argument itself, such as, for example, the motor features in the case of action-related words.

Furthermore, evidence of a motor deactivation during the processing of negative sentences has been reported also by studies employing experimental tools that record muscle activity, such as grip force (Aravena et al. 2012) and kinematic variation analysis (Bartoli et al. 2013), and Electromyography technique (Foroni and Semin 2013). Aravena et al. (2012) presented participants with recorded affirmative (68) and negative (69) sentences describing hand actions, and affirmative sentences consisting of an abstract verb followed by a concrete noun (70). During the listening, the force with which participants held a grip force

[53] Event-related Desynchronization

[54] English translation of the original Italian sentences: (66) Ora scrivo/ Non scrivo; (67) Ora immagino/ Non immagino

sensor[55] was analysed: since grip force reflects neural activity in motor brain structures, the authors were expecting an immediate increase in grip force while listening to sentences containing hand actions.

(68) At the Gym, Fiona lifts the dumbbells
(69) In the plane, Laura does not lift her luggage
(70) In the spring, Edmond loves the flower bush in the garden

In line with previous experiments using different neuro-imaging tools, results showed a significant increase of grip force with action verbs, but, crucially, only in the affirmative condition (68). In addition, abstract verbs (70) did not produce any variation in the grip force modulation, further confirming that they do not enhance the activation of motor brain areas. It is also worth noting that the grip force modulation was neither affected by the presence of a concrete noun (e.g., *flower bush*) in (70). This suggests that the activation of motor brain areas is not simply associated with the concreteness of the word, but rather with its relationship with motor activities. In turn, Foroni and Semin (2013) focused on the role of negation during the interpretation of emotional expressions. Participants were auditorily presented with affirmative and negative statements, which could describe either a zygomatic activity (71) or not (72). While listening, zygomatic muscle activity was continuously measured using the Electromyography technique (EMG)[56].

(71) I am/am not smiling
(72) I am/am not frowning

Similarly to Aravena et al. (2012), results indicated a significant activation of the zygomatic muscle only with affirmative sentences describing zygomatic activity (e.g., *I am smiling*). Given the high temporal sensitivity which characterizes this technique, the authors have observed that with the corresponding negative sentences (e.g., *I am not smiling*) the inhibition of the zygomatic muscle occurred within 500-700ms from the onset of the stimuli. This provides further evidence that the inhibitory effect of negation on the information under its scope affects the processing very early. Again, as concerns verbs describing other types of emotion not related to motor activities, no muscle activation was detected.

Bartoli et al. (2013) started from the consideration that, if the processing of linguistic statements describing motor activities grounds on the same neuronal circuits employed for the execution of the activity itself, the simultaneous execution

[55] The sensor held by participants captures subtle grip force variations which reflect motor activity in brain areas during the execution of a linguistic task. The monitoring of force modulations provides a high temporal resolution of the collected data.
[56] Electromyography (EMG) measures the electrical activity produced by muscles in response to either electrical or neurological stimulations.

of a motor activity and the comprehension of a corresponding sentence should be facilitated when the latter is negative rather than affirmative. Given the early suppressive effect of negation, the motor brain areas would not be involved in the processing of the negative sentence but only in the execution of the related motor activity. Instead, during the processing of affirmative sentences, the motor neuronal circuits would be overloaded by the simultaneous execution of two different tasks (i.e., linguistic processing and motor activity), resulting in a more effortful execution of the motor activity compared to when the sentence is negative. The authors conducted two experiments to test this hypothesis. Participants were presented with affirmative and negative sentences containing abstract verbs (73), proximal activities (74), and distal activities (75). In the first experiment, while listening to the sentences, participants were asked to perform a proximal reach-to-grasp movement with their fingers towards an object. In the second experiment, instead, they were asked to perform a grasp-distal movement (i.e., grasping without reaching). The same set of linguistic stimuli was presented in both the experiments.

(73) I do not wish / wish
(74) I do not grasp / grasp
(75) I do not pinch / pinch[57]

Results showed that, when participants were asked to perform a proximal movement, the interpretation of negative proximal sentences (e.g., *I do not grasp*) interfered less with the execution of the reach-to-grasp movement, as indicated by faster reaction times in the motor task with respect to affirmative proximal sentences (e.g., *I grasp*). This facilitating motor effect was not found in abstract and distal sentences. A similar pattern of results was found when participants had to perform a grasp-distal movement, with a reduced interference only when the manual task was performed simultaneously to the listening of negative distal sentences (e.g., *I do not pinch*). None of the other types of sentences reported this facilitating effect. The facilitating effect found among negative sentences seems to corroborate the authors' hypothesis that motor brain areas are not involved during negation processing. Furthermore, the facilitating effect of negation is closely associated with the execution of tasks closely related to the semantics of the negated concept (e.g., the sentence *I do not grasp* facilitates the activity of grasping an object, while the sentence *I do not pinch* facilitates the activity of grasping but not reaching).

Taken together, these neurolinguistic findings strongly speak in favour of an incremental view of negation processing. The neural representation of affirmative

[57] English translation of the original Italian sentences: (73) Io non/auspico; (74) Io non/afferro; (75) Io non/pizzico

sentences and that of the corresponding negative sentences are immediately distinguishable in the brain: while the processing of affirmative action-related sentences induces the activation of motor areas, the presence of linguistic negation inhibits the activation of the very same brain networks. Thus, negation seems to be immediately integrated into sentence meaning, as the suppression of the negated information occurs during the earliest moments of sentence comprehension as soon as semantic effects are observable in the brain.

It is worth noting, however, that alternative accounts have reconsidered the functional role of sensori-motor systems in language processing, providing alternative interpretations for the reported findings. For instance, Patterson et al. (2007) assumed that the activation of motor brain areas determined by language processing is a direct consequence of a spreading activation from other neuronal regions where the representations underlying language comprehension occur (*Secondary embodiment*). Under this view, the semantic representations are completely unrelated to sensori-motor information: hence, the activation of motor brain areas is not mandatory for the retrieval of linguistic information, but, rather, it occurs when motor features related to the word meaning are required by the context. Instead, Mahon and Caramazza (2008) proposed that the activation of motor brain areas simply integrates the more abstract representations underlying language comprehension (*Grounding by interaction view*).

Neurolinguistic evidence of a very early inhibitory effect of negation during sentence comprehension poses a significant problem for non-incremental models of negation processing. On one hand, supporters of the Two-Step Simulation Hypothesis do not consider the suppressive nature of negation at odds with a two-stage based processing, as the inhibition of the information occurring under the scope of negation might correspond to the second stage of sentence comprehension. On the other hand, however, the Two-Step Simulation Hypothesis assumes an experiential view of language comprehension, which is based on neurolinguistic findings showing an overlap between the mental subsystems involved in the representation of linguistic information and those involved in perceiving or enacting the same situations. According to this motor-sensorial view of language, understanding a sentence means to mentally experiencing it (for a more detailed analysis see §2.2.1.3). Nonetheless, the embodiment cognition studies discussed in this section have clearly shown that the activation of motor brain areas, typically elicited by affirmative sentences, are instead immediately blocked during the comprehension of negative sentences. This strongly rules out the possibility of a prior stage of sentence processing in which occurs a mental simulation of the positive state of affairs, with only a later integration of the negative sentence meaning.

Nevertheless, embodiment cognition studies have investigated, so far, a very restricted range of verbs and negative constructions: as we have seen in this section, the researchers mainly focused on simple and short declarative sentences with first-person singular action verbs, in particular hand-related ones. Moreover, participants were mainly presented with passive listening tasks, which are not particularly demanding in terms of processing resources since they do not require, for example, the evaluation of the truthfulness of the test sentences. This represents the main limitation of neuro-imaging studies, which, so far, have provided evidence concerning only limited aspects of negation processing[58]: thus, they can only be partially compared with experimental findings from traditional behavioural studies, which have investigated more complex and heterogenous structures within elaborated verification paradigms.

2.3 Concluding remarks

Despite the fact that sentential negation is still a widely-investigated linguistic phenomenon, in this chapter we have seen how psycholinguistic researchers are still debating on some core aspects of its processing: namely, the timing and mode of negation integration, and the role of the information occurring under the scope of negation during the sentence interpretation process.

Non-incremental models of negation processing (§2.2.1), and in particular the Two-Step Simulation Hypothesis (Kaup et al. 2007), assume that negation is not immediately integrated into sentence meaning, as the interpretation of a negative statement requires the former evaluation of its positive counterpart. This additional computational step involved in the comprehension process makes the computation of negative sentence inherently more complex than that of affirmatives, and would be responsible for the higher processing costs which are largely attested for negative sentences (Wason 1961; Clark & Chase 1972; Carpenter & Just 1975; Kaup et al. 2005, 2007, Lüdtke et al. 2008; Vender & Delfitto 2010; among others). A large number of experimental studies indeed speak in favour of a late inhibition of the information occurring under the scope of negation, which seems to be retained during the earliest moments of sentence processing for the mental simulation of the negated state of affairs. Moreover, a facilitating effect on the processing has been reported when negative sentences are presented in a pragmatically felicitous context, consistent with the negated state of affairs (e.g., false negative condition in a sentence-picture verification set-up). This evidence in support of a non-incremental processing of negation comes from classical experimental paradigms of language comprehension, such as sentence-picture verification task (Carpenter & Just 1975; Kaup et al. 2005, 2006, 2007, 2007b; Lüdtke & Kaup 2006; Vender

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[58] For instance, Bartoli et al. (2013) hypothesized that, in order to evaluate the truthfulness of a sentence, it might be necessary to simulate both the negated and the actual state of affairs: during this process, the deactivation of motor brain areas which characterizes the processing of negative sentences might be preceded by an initial stage of motor activation.

& Delfitto, 2010) and lexical decision task (Hasson & Glucksberg 2006), and also from EEG-ERPs studies (Fischler et al. 1983; Lüdtke et al. 2008).

On the other hand, incremental accounts of negation processing (§2.2.2) have reported contrasting evidence, showing that sentential negation is very rapidly integrated into the semantic meaning of the sentence, resembling the interpretation process of affirmative statements. This view considers the higher processing costs reported for negative sentences merely as the consequence of a pragmatically infelicitous context of utterance: in classical sentence-picture verification set-ups, negative sentences are in fact often employed in isolation, deviating from their use in everyday communication. Hence, when a supportive discourse context is provided, the processing of negative sentences would not be more demanding than that of the corresponding affirmative sentences, as the mental simulation of the negated state of affairs is not a mandatory step in the comprehension process. Indeed, a consistent number of behavioural and EEG-ERPs studies have provided compelling evidence that the higher processing costs for negative sentences can be significantly reduced when presented in a supportive context of utterance (Wason 1965; De Villiers & Flusberg 1975; Glenberg & Robertson 1999; Dale & Duran 2011; Nieuwland & Kuperberg 2008; Staab et al. 2008). Moreover, the possible retainment of the information occurring under the scope of negation seems to be significantly affected by the contextual information provided (Giora et al. 2004, 2005, 2007; Giora 2006; Paradis and Willners 2006) and by the types of predicates and terms involved (Mayo et al. 2004; Orenes et al. 2014).

If a facilitating effect on the computation in pragmatically felicitous contexts is predicted also by the Two-Step Simulation Hypothesis, the most persuading evidence for an early integration of negation into sentence meaning, and thus of an incremental processing, is provided by neuro-imaging studies. Embodiment cognition research has shown that, in fact, the processing of negative sentences induces a very *early* inhibition of those brain motor areas which are usually activated by the computation of the corresponding affirmative statements (Tettamanti et al. 2008; Tomasino et al. 2010; Liuzza et al. 2011; Alemanno et al. 2012; Bartoli et al. 2013; Foroni and Semin 2013). This neurolinguistic evidence poses a significant problem for the Two-Step Simulation Hypothesis: while it is true that the suppressive nature of negation is not at odds with a non-incremental view of negation processing, the Two-Step Simulation Hypothesis considers the mental representations involved in language comprehension to be experiential in nature, featuring the activation of those motor brain areas involved in perception and action (Zwaan & Radvansky 1998; Pulvermüller et al. 2001; Pulvermüller 2002; Zwaan & Taylor 2006; Zwaan 2004; Kaup et al. 2007). Nonetheless, neurolinguistic studies have focused only on a limited set of hand-action related verbs presented without any linguistic or more general discourse context. Though extremely promising, neuro-imaging evidence is therefore hardly comparable with results from more classical experimental paradigms, which investigated more complex sentence structures and the role of the contextual cues in the interpretation process.

The findings reported by classical experimental paradigms on language comprehension and neurolinguistic techniques thus appear quite puzzling and, in some respects, also contradictory. In addition, sentence-picture methodology generally assesses sentence comprehension in terms of response latencies and accuracy in expressing metalinguistic judgements about what the listeners have observed and heard during the test trial. This represents one of its major limitations for the investigation of negation process: while the behavioural measures collected can give relevant insights on the final comprehension of the negative sentence, they do not provide any precise information on how the listeners reach this ultimate understanding. The same limitations hold for the reported EEG-ERP studies, which were always conducted within a sentence-picture verification set-up.

Far from being conclusive, in the next chapter we will see how the theoretical debate on the processing of sentential negation can benefit from the use of the *visual world paradigm*, an experimental methodology which employs online measures of sentence comprehension.

3 Using the Visual World Paradigm to study language processing

In the previous chapter, we have outlined the theoretical aspects concerning the processing of sentential negation, by drawing particular attention to how psycholinguistic research has provided, so far, conflicting evidence on the timing and the mode of negation integration, and on the role of the argument of negation in sentence processing.

In this third chapter, we will introduce the *visual world paradigm,* an experimental methodology which employs the recording of participants' eye movements during listening (and reading) tasks. Although at the moment there is little psycholinguistic research that has investigated the processing of negation within the *visual world paradigm*, we will see that eye movement data can give important insights on how visual and linguistic stimuli interact during the comprehension of negative sentences, making a decisive contribution to the broad theoretical discussion on negation processing. In the first section of this chapter (§3.1), we will review the pioneering eye-tracking studies which have led to *the visual world paradigm*. In §3.2, we will first outline the key features of visual world studies on language processing: after a brief overview of the most common eye-tracking devices, we will offer some insights on the eye movement analysis. Then, we will discuss some of the most important visual world studies on language comprehension at word (§3.2.3.1) and sentence level (§3.2.3.2), focusing on those aspects of the processing which will be of central interest for the aim of the present study, such as the integration of different types of information during the processing and effects of lexical activation. In the third section of this chapter (§3.3), we will review two particularly relevant studies on negation processing: throughout the discussion, we will underline some important limitations of these studies as concerns the result interpretation as well as the experimental set-up, which will be the starting point for the development of the present eye-tracking study on negation processing (chapter 4). In the final sections we will extensively discuss the advantages of the use of the *visual world paradigm* in the investigation of negative sentence processing with respect to more classical experimental paradigms as those described in chapter 2, in order to motivate its adoption for the present research. Significantly, some important experimental limitations which are intrinsically related to the visual nature of the paradigm will also be discussed. Based on these considerations, in §3.5 we will describe the relevant modifications to the classical visual world set-up which we will introduce in our eye-tracking study, and we will outline our main research questions.

3.1 Early studies: the development of the Visual World Paradigm

Cooper (1974) conducted the first eye-tracking study with the aim of investigating the real-time interaction of perceptual and cognitive processes during spoken language comprehension. Participants were simultaneously presented with spoken short stories and a visual display containing black and white drawings of common concrete objects (e.g., a lion, dog, zebra, camera or queen). Some of these pictures were related to the stories, as the depicted objects were directly mentioned or were semantically related to target words presented in the spoken text (in italics in (1)). Consider for instance a visual display as Figure 3.1 accompanying a short narrative about a safari in Africa (1): while words such as *lion* and *zebra* have a direct visual referent on the screen, the word *Africa* is only semantically related to the pictures of animals such as a lion, a zebra, and a snake, which are known to be part of the African wildlife.

(1) While on a photographic safari in *Africa*, I managed to get a number of breath-taking shots of the wild terrain. (…) When I noticed a hungry *lion* slowly moving through the tall glass toward a herd of grazing *zebra*.

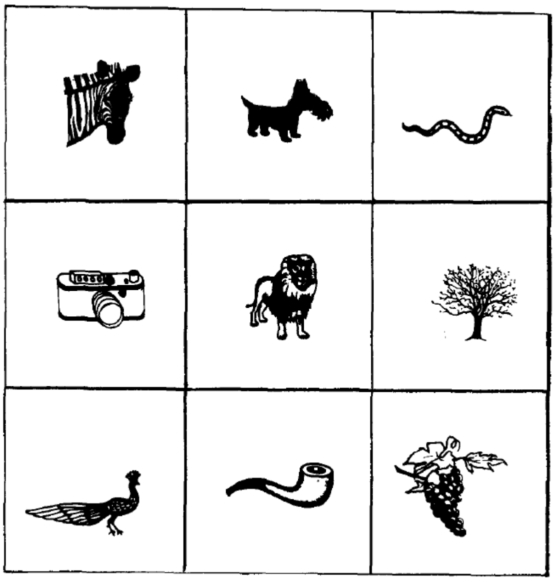

Figure 3.1. Visual scenario for the narrative in (1)

Participants were asked to listen to the short stories while looking anywhere they wanted on the screen. During the task, their eye movements were recorded using an eye movement camera system (Mackworth 1968). Despite these instructions, Cooper found that participants focused their gaze more towards the objects which were to some extent related to the text than towards unrelated ones. For instance, in (1) the listeners were more attracted by the picture of a lion than by that of a zebra while hearing the word *lion*; similarly, their visual attention was drawn by pictures of African animals (e.g., zebra, lion, snakes) rather than by the picture of a dog when the word *Africa* was pronounced. In addition, Cooper observed that the looks at the objects in the visual scenario were closely time-locked to the presentation of the linguistic input, with significant patterns of fixations to the related pictures while the target words were uttered or within 200ms after their offset. Thus, listeners seem able to actively exploit anticipatory cues from the speech stream, such as word initial phonemes or syllables, to make predictions concerning the upcoming linguistic information. All in all, this pattern of findings represents the first experimental evidence that spoken language guides visual attention: language-oriented eye movements are often fast and unconscious, as they reflect the online activation process of word semantics that occurs incrementally during the unfolding of the linguistic input.

In line with these findings, Just and Carpenter (1980) accounted for eye movements and fixations during written language comprehension. College students were presented with technical texts about unfamiliar topics (e.g., the properties of fly-wheels), which were rated as difficult based on Flesch's (1951) readability scale. They were asked to read these passages as naturally as possible without memorizing, and to recall their content after reading. During the experimental session participants' eye movements were recorded by a television camera. Quite surprisingly, results showed that the duration of the fixations significantly differed from word to word within each passage. This evidence has led Just and Carpenter to the formulation of the influential *Eye Mind Hypothesis*, according to which eye movements reflect the cognitive processes involved in the comprehension of written language. During reading, the parser fixates a word as she is processing it, and the duration of this fixation reflects the processing load required during the comprehension process. Hence, the readers would make longer fixations when the processing is more effortful, as for example when they encounter infrequent or more complex words in the text, or when they are integrating contextual information provided either by previous linguistic information or by their encyclopaedic world knowledge.

These studies represented the first experimental evidence of a real-time interaction between visual attention and language comprehension, as they showed that the parser immediately integrates written and spoken linguistic information with that provided by the visual context. Cooper (1974) recognized the advantages of the eye movement analysis for investigating how perceptual and cognitive processes jointly determine the on-line understanding of linguistic sentences, considering the eye-tracking methodology a useful research tool for the study of speech perception and language processing. Nevertheless, his work has been largely ignored for more than twenty years until in the early 90s psycholinguists to start exploiting the eye-tracking technology in the study of language processing with the rise of the so-called Visual World Paradigm (Tanenhaus et al. 1995, Allopenna et al. 1998). This initial lack of interest for the investigation of the interplay between linguistic and visual information processing is presumably due to the fact that, at the time, the psycholinguistic community was dealing with other research topics such as the processing and the representation of syntactically complex sentences (e.g., Forster, 1970; Hakes, 1972; Holmes & Foster, 1972). Furthermore, the late development of the Visual World Paradigm is also strictly connected to Fodor's influential idea of the *modularity of mind* (1983), which has been widely accepted and further elaborated by psycholinguistic research throughout the following decades. According to *modularism*, the mind consists of independent and domain-specific cognitive modules (e.g., vision, memory, language), which are innate and implemented in a fixed neural architecture. These cognitive modules are considered to be informationally encapsulated: they process a given input automatically and independently from one another, and, crucially, during this processing they cannot access information stored in the other cognitive domains. It is thus quite intuitive how a theoretical perspective which considers language and vision as autonomous and encapsulated cognitive modules has consequently aroused little interest among researchers for the investigation of a possible interaction between linguistic and visual sources of information during sentence processing. Nevertheless, the notion of cognitive modularity has been strongly challenged from the 90s onward, when psycholinguists have renewed their interest in determining how linguistic and perceptual processes jointly determine language comprehension. The study by Tanenhaus and colleagues (1995) had a key role in the development of this research field, as it provided compelling evidence against the modularity of cognitive processes.

Tanenhaus et al. (1995) employed the eye-tracking methodology to investigate the effects of the visual context on language comprehension and understand whether visual contextual information can affect the syntactic processing. Participants were presented with sentences either containing (2) or not (3) temporary syntactic ambiguities. In (2), the prepositional phrase *on the towel* is ambiguous between being a modifier of the DP *the apple* (i.e., indicating the location of the apple to be picked up) and indicating the destination of the action (i.e., the place where the apple has to be put).

(2) Put the apple on the towel in the box
(3) Put the apple that's on the towel in the box

While listening to these instructions, participants were presented with two types of visual scenarios that supported one of the possible interpretations of the ambiguous PP. The one-referent context (Fig. 3.2a) contained four set of objects: a pencil, a box, a towel with nothing placed on it, and one apple placed on a towel. Such a visual scenario suggested an interpretation of the PP *on the towel* as destination place: when hearing the DP *the apple*, the listener was immediately able to identify the object to be moved because there was only one apple in the context and, hence, it was likely to assume that *on the towel* referred to the destination of the action of putting rather than to another peculiar property of the apple itself. Conversely, in the two-referent context a second apple placed on a napkin was presented instead of a pencil (Fig. 3.2b). Here, the DP *the apple* did not have a univocal visual referent, and, hence, it was more likely for the listener to interpret the PP *on the towel* as a modifier which provided specific information about which apple had to be moved.

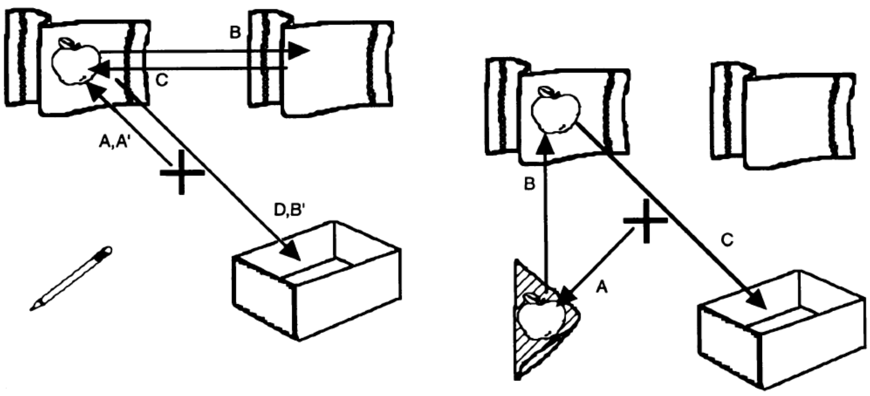

Figure 3.2. Visual scenarios for the one-referent (a) and the two-referent (b) contexts – from Tanenhaus et al. (1995)

According to modular theories, the parser cannot access information provided by other cognitive domains during syntactic processing: hence, this type of syntactic ambiguity would be resolved independently from the communicative context in which it is presented, with the parser always showing a clear preference for an interpretation of the PP *on the towel* as destination of the action for reasons of syntactic requirements of the ditransitive verb *to put*. Instead, if visual contextual cues are integrated in the syntactic processing as soon as the linguistic input unfolds, a relevant experimental context might influence the parsing and the resolution of the syntactic ambiguity, resulting in a different interpretation of the same PP *on the towel* in the two conditions.

The eye movement analysis showed different patterns of fixations in the two visual contexts. When the ambiguous sentence (2) was presented in a one-referent context, participants initially interpreted the PP *on the towel* as destination place. 500ms after the offset of *the apple* they were looking at the target object, participants switched their gaze towards the wrong destination (e.g., the empty towel) shortly after hearing *the towel*; then, they focused again on the apple and eventually on the box. This pattern of eye movements clearly indicates that they had initially interpreted the PP *on the towel* as destination place, as also suggested by the fact that when the same visual context was accompanied by the unambiguous sentence (3), participants never looked at the empty towel. In the two-referent context participants looked at both the apples after that the object was mentioned.

Significantly, referent resolution took almost the same time both with ambiguous (2) and unambiguous (3) sentences: after looking at the apple placed on the towel, participants immediately focused on the box without paying attention to the incorrect destination (e.g., the empty towel). This is evidence that, in the two-referent context, the PP *on the towel* was immediately interpreted as modifier of the object and not as destination, regardless of the syntactic configuration of the test sentence. Taken together, these results provide strong evidence against the encapsulation of cognitive processes such as vision and language. By monitoring eye movements, Tanenhaus et al. (1995) clearly demonstrated that the visual context can significantly affect spoken language comprehension from the earliest moments of the syntactic processing as soon as the linguistic input unfolds.

In conclusion, the work by Tanenhaus et al. (1995) provides evidence of a real-time integration of linguistic and non-linguistic sources of information during language processing, drawing attention to the great potential of the eye movement analysis for the investigation of the cognitive processes underlying the online understanding of the linguistic input. This, together with the fact that in the 90s the eye-tracking technology started to become more accurate and cheaper, has led to an increase in the use of the Visual World Paradigm to study spoken language processing. Although from the beginning visual research mainly focused on language comprehension, eye-tracking technology has been soon adopted to investigate the cognitive processes underlying language production (Meyer et al. 1998; Griffin & Bock 2000; among others).

3.2 Visual world studies on language processing

In this section, we will first outline the key features which characterize the studies on language processing conducted using the Visual World Paradigm (§ 3.2.1): given that, as previously mentioned, most of the visual world studies conducted deal with language comprehension processing, we will describe in detail the experimental properties of the paradigm as used in this research field. After a brief overview of the most common measurement devices which have been employed over time to track eye movements, we will provide some insights about how the eye movement analysis works, and how raw data obtained from the eye tracker (e.g., fixations and saccades) can be interpreted in relation to the linguistic input provided during task execution (§3.2.2). As concerns language comprehension, we will review the main research areas of visual world studies, which have investigated different aspects of the linguistic processing at word- and sentence-level (§3.2.3). In particular, we will focus on studies on sentence comprehension which constitute a relevant theoretical background for the aim of the present study.

3.2.1 Key features

In a typical visual world comprehension study, participants are simultaneously presented with a visual display and a spoken linguistic input. The classical version of the experimental set-up is based on the design adopted in Cooper's pioneering study (1974), with usually four black and white line drawings of common objects shown on a computer screen (e.g., Figure 3.4 from Huettig & McQueen 2007). Another widely employed version of the visual input consists of drawings of semi-realistic scenes, where objects are not merely depicted in fixed positions on the screen, but they appear within a more organized and realistic environment, providing an experimental setting which is closer to the natural context of utterance of the linguistic input. This type of visual scenario has the advantage of allowing the investigation of how language processing is affected by the listener's perception of the discourse context.

For instance, Altmann & Kamide (1999) employed a semi-realistic visual scene to investigate whether the semantic information conveyed by the verb can anticipate the interpretation of upcoming relevant linguistic information. While listening to the sentence *The boy will eat the cake*, participants were presented with a visual scene showing a young boy sitting on the floor, surrounded by different items: a toy train set, a toy car, a birthday cake, and a balloon (Figure 3.3).

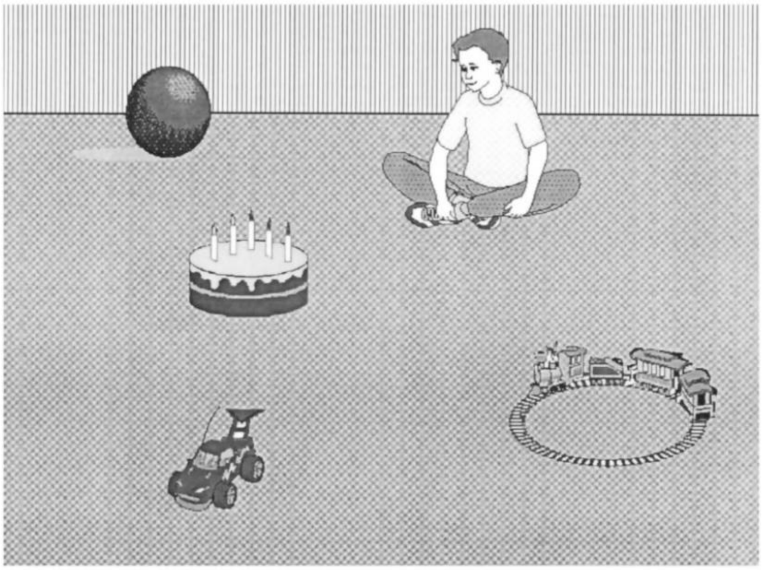

Figure 3.3. Example of a semi-realistic scene for the sentence "The boy will eat the cake" - from Altmann & Kamide (1999)

While the outcomes of this study will be discussed in detail in §3.2.3.2, at this point of the discussion it is worth noting that the visual scenario typically includes both relevant objects and distractors. The former can be either directly mentioned in the linguistic input - such as the boy and the cake in Altmann & Kamide (1999), or indirectly related to it - such as the snake in Cooper (1974), which was semantically related to the word *Africa*. Instead, the distractors are objects which are not mentioned in the linguistic input and are completely unrelated to it – such as the ball in Altmann & Kamide (1999). Usually, the presentation of the visual display begins either simultaneously with or shortly before the onset of the spoken utterance, so that participants have a few seconds to familiarize with the objects presented in the visual scenario before the onset of the critical word (e.g., the verb *eat* in the previous example from Altmann & Kamide, 1999). The visual scenario stays in view until the end of the linguistic input, and participants have to press a button to continue with the next trial.

Recently, a printed-word version of the paradigm has been developed, where the display contains the written names of the objects instead of the corresponding pictures (Huettig & McQueen 2007; McQueen & Viebahn 2007). An important advantage of this printed version is its greater sensitivity to phonological manipulations compared to the traditional set-up with depicted objects (Weber et al. 2007; Huettig & McQueen 2007; Salverda & Tanenhaus 2010). In a series of visual world studies, Huettig and McQueen (2007) asked Dutch participants to listen to a sentence such as (4), containing the target word *beker* (beaker), while on the visual display were presented phonological (*bever* - beaver), shape (*klos* - bobbin), and semantic (*vork* - fork) competitors of this target word, either as drawings (Figure 3.4b) or printed versions of the same items (Figure 3.4a).

(4) Eventually she looked at the beaker that was in front of her

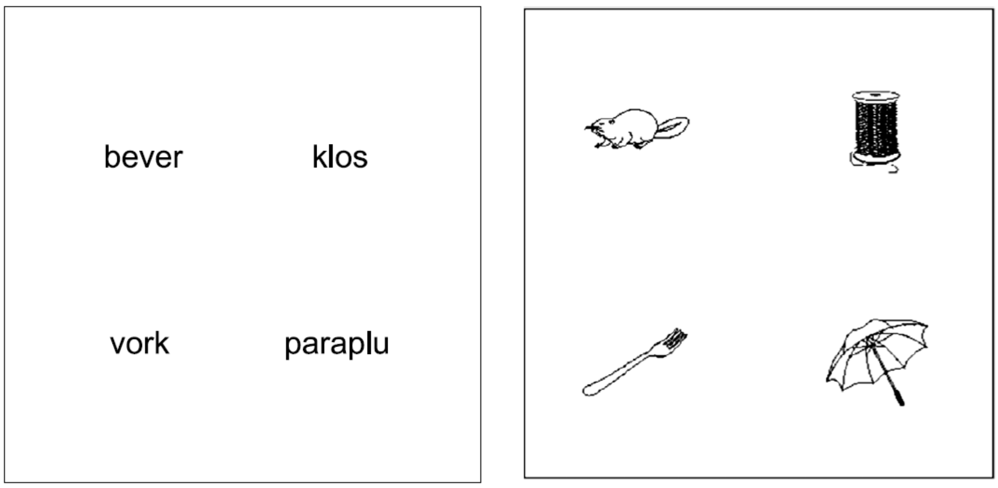

Figure 3.4. Example of a printed-word (a) and four-object-display (b) version of the visual display from Huettig and McQueen (2007) for the sentence in (4)

Results clearly indicated that visual attention shifts were also determined by the nature of the information provided by the visual context: when visual stimuli consisted of pictures, participants' fixations were directed to shape (i.e., bobbin) and then semantic (i.e., fork) competitors; instead, when the visual scenario contained the printed names of the objects, participants focused their visual attention only towards phonological competitors (i.e., beaver).

This brief review has shown how the choice of the experimental set-up is closely linked to the research questions that each visual world study aims to address. The same holds for the choice of the task: spoken utterances can be presented to subjects in the form of instruction - as we have seen in Tanenhaus et al. (1995), where participants were asked to pick up an apple and move it to another location on the workspace, or as mere descriptions of the visual scene (e.g., Altmann & Kamide 1999; Huettig & Altmann 2005; Huettig & McQueen 2007; among others). The latter is known as the *look-and-listen paradigm*: as the name suggests, participants are not asked to perform any explicit task, as they are only instructed to listen to the sentences carefully and look wherever they want on the visual screen. In such an experimental design, participants are not asked to do anything different from what they do in their everyday life when they need to integrated information from written and spoken sources (e.g., watching tv or reading illustrated texts). This is definitely an advantage compared to other psycholinguistic paradigms such as lexical decision or sentence picture verification tasks, where participants are asked to perform metalinguistic judgements about the linguistic input provided, either against pictures or their world knowledge (see chapter 2 for a detailed analysis). Participants' working memory resources are widely exploited during the performance of more complex metalinguistic evaluations, and this can crucially affect the way in which linguistic input is processed. Conversely, the simplicity of the *look-and-listen task*, and more in general of the visual world paradigm, makes the task execution extremely effortless for participants, as it only relies on their tendency to look at relevant parts of the screen as critical words are mentioned. Therefore, the data collected are not compromised by external factors such as mental fatigue, and they can provide extremely precise real-time data on the comprehension process. Significantly, this allows researchers to evaluate whether particular effects (e.g., semantic or phonological competition as in Huettig & McQueen 2007) are directly related to the interaction between visual and linguistic sources of information or whether they are merely the consequence of too demanding experimental tasks. Given the effortless nature of visual world studies, this experimental paradigm has also been used to test young children (Nation et al. 2010; Mak et al. 2013; Mani & Huettig 2014; Tribushinina & Mak 2016) and adolescents (Brock et al. 2008; McMurray et al. 2010) as well as impaired populations such as adults with aphasia (Thompson & Choy 2007; Walsh et al. 2007; Yee et al. 2008), and children (Rayner 1998; De Luca et al. 1999, 2002; Hutzler & Wimmer 2003; Desroches et al. 2006) and adults (Stoodley et al. 2006; Huettig & Brouwer 2015; Benfatto et al. 2016) with developmental dyslexia.

During the experimental session, participants' eye movements are recorded via an eye tracker. In the next section we will see how these raw eye movement data are further analysed with the aim of investigating the viewer's looking pattern behaviour during the simultaneous presentation of the linguistic input.

3.2.2 Eye Tracking methodology and data analysis

One of the earliest techniques developed for measuring eye movements required the use of a scleral contact lens. The first version of this measurement device consisted of a plaster ring mounted on a lens, which was directly attached to the cornea and mechanically linked to a recording pen (see Young & Sheena 1975 for a detailed review). Later, this prototypical tool has been replaced by a modern contact lens, large enough to cover both the cornea and the sclera: the lens is attached to a mounting stalk, which in turn is connected to a wire coil. The transmission of electric current through this wire creates an electromagnetic field: when the coil moves as a result of an eye movement, the electromagnetic field induces a voltage in the coil, signalling the eye position. Although this device is extremely precise for eye movement recording, it has important drawbacks. First, it is an intrusive technique, and wearing this type of lens is particularly uncomfortable for the subject. Second, the insertion of the lens itself requires extreme care and precision to avoid damaging the eye. Finally, the eye position is measured in relation to the position of the head, which, in turn, should be fixed and measured (e.g., using a head tracker) in order to ensure the correct tracking of eye movements.

During the 70s, the most employed technique for eye movement recording was the *electro-oculography* (EOG). This procedure involved the measurement of electric potential differences of the skin surrounding the ocular activity by means of electrodes placed around the eyes in fixed positions. Although electro-oculography is still used nowadays, it has been replaced by more modern recording techniques which, unlike EOG, do not measure eye movements in relation to the head position.

A more recent technique is *video-oculography* (VOG), which is based on the recording of observable ocular features (e.g., the apparent shape of the pupil or the iris/sclera boundary) and of corneal reflections provoked by a close infra-red light source directly pointing towards the eye. Since the ocular measurements are recorded by a video camera, this technique has the advantage of not being invasive for the patient. Nevertheless, it requires the researcher to subsequently perform a visual inspection of the recordings in order to assess the data collected, and this makes the operation extremely prone to manual errors. Moreover, as the other techniques described so far, video-oculography does not measure the position of the eye in the space but only in relation to the head position.

Nowadays, the most employed technique for measuring eye movements is the *video-based pupil-corneal reflection (P-CR) eye tracker*, which permits to disambiguate head movement from eye rotation, providing indication of how the viewer's gaze is oriented in the space. This is made possible by the measurement of different ocular features, namely the corneal reflection of an infra-red light source and the pupil centre. While the distance between the corneal reflection and the pupil centre changes with eye rotation, it essentially remains identical during little head movements. Variations in the distance between the pupil centre and the corneal reflection allows the eye tracker to establish the exact orientation of the viewer's gaze on the visual display. Significantly, the previous eye tracking techniques did not permit this spatial evaluation of the eye movements, which was possible only if the eye position relative to the head and the gaze direction coincided. In addition, unlike VOG, this video-based technique employs a computer-based automatic analysis of the video recording to compute the real-time eye movements without the intervention of the researcher.

The P-CR eye tracker can require head stabilization (*Desktop Mounted Version* – see Figure 3.5) during specific experimental tasks in order to obtain a greater precision in eye movement recording (e.g., reading task). However, the measurement system on which this apparatus is based does not make head stabilization always necessary: this is particularly useful for testing infants, children and atypical populations, who might have special needs during the experimental session, as they typically have difficulty in concentrating and sitting still for too long.

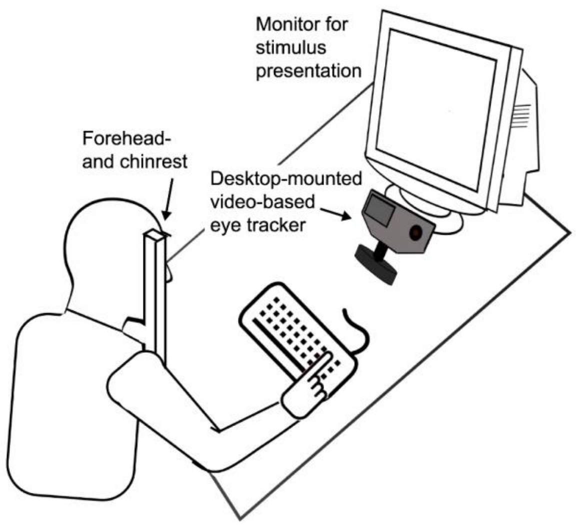

Figure 3.5. Example of a video-based eye tracker – desktop mounted version

The eye movement analysis aims at providing detailed information on the viewer's attentive behaviour during the simultaneous processing of the linguistic input. Modern P-CR eye tracking techniques provide a large amount of accurate eye movement data: for instance, the EyeLink 1000 Plus (which we employed for our eye tracking experiments in chapters 4 and 6) can sample either a single eye at 2000

Hz, measuring the eye position every 0.5ms, or both eyes at 1000 Hz, with an eye measurement every 1ms. Nevertheless, without further analysis, the raw data extracted from the eye tracker are not informative with respect to the research questions concerning the viewer's looking pattern behaviour during the task execution. Thus, the first step of the analysis requires extracting from the raw data set salient eye movement *events*[59], namely fixations and saccades, which can provide evidence of the viewer's overt visual attention. In particular, fixations occur when the gaze is maintained on a stable object of interest, hence indicating where on the screen the viewer is paying attention; saccades are instead rapid eye movements which allow the viewer to change her focus of attention from one point to another in the visual environment[60].

Figure 3.6 shows a hypothetical eye movement signal. During a fixation, the y-coordinate of the signal (i.e., the position of the eye on the visual display) remains stationary, indicating that over a given period of time (i.e., x-coordinate) the eye is fixating a specific point on the visual display. An abrupt change of the y-coordinate indicates the onset of a saccade, during which the viewer rapidly shifts her gaze from one point to another. Unlike fixations, saccades are extremely fast eye movements, ranging in duration from 10 to 100ms: this is evidenced by the fact that, during the saccade, the x-coordinate remains almost unchanged. Finally, when the y-coordinate returns stable, a new fixation begins, but, significantly, elsewhere on the screen compared to where the former fixation occurred.

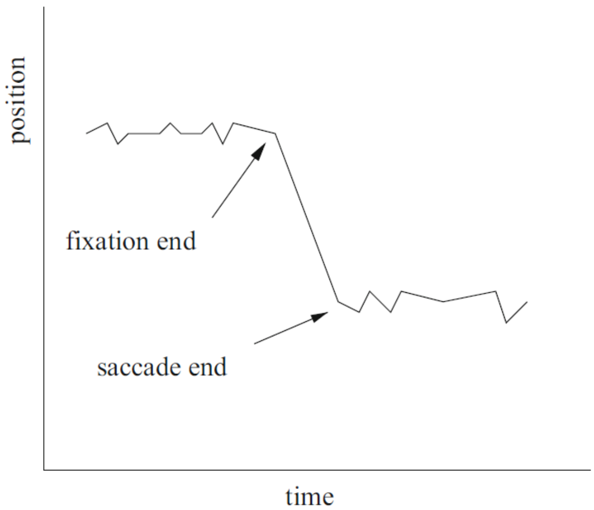

Figure 3.6. Example of a hypothetical eye movement signal (Duchowski 2003)

[59] Depending on the analysis required, other relevant eye movement events can be extracted from the raw data (e.g., smooth pursuit, pupillometric data and micro-saccades).
[60] Saccades can be voluntary executed or reflexive, being in the latter case a corrective optokinetic or vestibular measure (Duchowski 2003). In either case, once that the saccadic movement towards another fixation point has been calculated, this cannot be altered.

Once that salient eye movement events are extracted from the raw dataset, they are employed as dependent variables to analyse how likely participants are to look at specific areas of interest in the visual scenario at different times during the trials. The selection of the areas of interest depends on the research questions: for instance, in a four-object display as in Huettig & McQueen (2007), there are usually four broad areas of interest, corresponding to the quarters of the screen where pictures are positioned (Figure 3.4). Indeed, Huettig & McQueen (2007) were interested in investigating possible competition effects among the different objects displayed on the screen, which represent phonological, semantic and shape competitors of a target word (see §3.2.1 for further experimental details). The statistical analysis of the fixation proportions in the different regions of interest revealed that, after the onset of the critical word, participants focused their gaze on the picture representing the shape competitor, as indicated by a significantly greater number of fixations directed to that region of the visual screen. Also the length of the time-windows depends on the research questions: however, since researchers are usually interested in participants' looking pattern behaviour during or immediately after the presentation of a target word in the linguistic input, the beginning of the time-window usually corresponds to the target word onset. More time-windows are usually analysed within the same experiment to better understand the online interaction of visual and linguistic stimuli during the language comprehension process.

Lastly, it is important to underline that visual world studies must account for a *baseline effect* in the data analysis. Trivially, a participant may be looking to one of the pictures on the visual display (e.g., a competitor of the target) before the onset of the critical word in the linguistic input: in this case, participant's fixations to a given picture would be biased, and they would not provide information about the real-time processing of the speech signal. In order to avoid this *baseline effect*, each experimental trial is usually preceded by a central fixation cross, which is displayed on the screen for a short period of time: in this way, when the trial starts, participants will be looking at the centre of the screen rather than at one of the critical pictures. In addition, fixations are always averaged across trials and participants, to avoid that discrete saccades and fixations by a single subject might biased the analysis of the proportion of looks in the regions of interest. Moreover, it can also be computed how likely participants are to look at each of the areas of interest during the trial, before the onset of the critical word. For instance, consider again a four-object visual display as in Huettig & McQueen (2007): given the four areas of interest in which the visual scenario is divided, participants have a 25% chance of being already looking at one of the four pictures before the word onset. This percentage represents the baseline for the proportions of fixations for each picture, and, thus, it cannot be considered as evidence of an intentional gaze shift, indicating, for instance, the gradual activation of a word competitor. Therefore, this chance level must be taken into consideration when interpreting the eye movement outcomes of a visual world studies.

3.2.3 Studies on language comprehension

In this section, we will provide an overall review of the main studies conducted within the visual world paradigm to investigate language comprehension, divided into two broad research areas: visual world studies at the word- (§3.2.3.1) and sentence-level (§3.2.3.2). Particular attention will be devoted to aspects of the processing which constitute the relevant theoretical background for our study on the processing of sentential negation in chapter 4, such as the integration of different sources of information and the issue of lexical activation.

3.2.3.1 Language comprehension at word level

Most of the visual world studies dealing with language comprehension at word level have focused on lexical processing, investigating, in particular, the role of phonological cues in lexical activation, word recognition in bilingual subjects, word-level semantic and perceptual processing, and how language- and visually-derived representations are integrated during spoken language comprehension. In this section, we will report some of the most relevant findings of these research areas, also drawing attention to some intrinsic limitations of the visual paradigm, which we will also find at other levels of the linguistic analysis.

In the last decades, one of the key issues in psycholinguistic research has been how, and to what extent, the processing of phonetic and phonemic cues can affect spoken word recognition during the real-time unfolding of the linguistic input. While already in the late 70s it has been demonstrated that lexical items displaying a word-initial phonological overlap (i.e., cohort competitors) systematically interfere in target word recognition (Marslen-Wilson & Welsh 1978; Marslen-Wilson 1987), little was known at the time about the role played by other phonetic details in lexical processing.

One of the most influential visual world studies in this field of research was conducted by Allopenna et al. (1998), who employed the eye-tracking technology to investigate the role of rhyme competitors during spoken word recognition. Participants were presented with four pictures of objects, including a target object (e.g., a beaker), a cohort competitor, whose name began with the same phonological onset of the target object (e.g., a beetle), a rhyme competitor, with a different onset with respect to the target word (e.g., speaker), and an unrelated competitor (e.g., a carriage). In the meantime, they were given spoken instructions to move the target object from one position in the visual display to another (e.g., *Pick up the beaker, now put it below the diamond*). Eye movements analysis showed a significant increase of fixations on the picture of the beetle as soon as the target word *beaker* was heard: however, when the acoustic stream started to be phonologically inconsistent with the word *beetle*, the fixations on the corresponding picture decreased, with participants paying increasing attention to the picture of a beaker. Significantly, the fixations on the picture of a speaker started to increase only when the target word *beaker* has been uttered completely. Taken together, these results provide important evidence that also rhyme competitors affect lexical activation, even if to a lesser degree than cohort competitors, which instead compete with target word activation earlier and more strongly during the unfolding of the linguistic input (see also Magnuson et al. 2003). Moreover, this pattern of findings clearly suggests that lexical activation is an incremental and continuous process, as assumed by continuous mapping models of spoken word recognition, e.g., the TRACE model of speech perception (McClelland & Elman 1986), and Shortlist B, the Bayesian model of continuous speech recognition (Norris 1994; Norris & McQueen 2008). Listeners seem able to retrieve and activate semantic and perceptual representations as soon as the speech input unfolds, and they exploit this information in order to identify possible referents from the visual context.

Numerous visual world studies have investigated the real-time processing and integration of phonetic cues (Dahan et al. 2001; Magnuson et al. 2007; Mitterer and McQueen 2009; among others). In particular, Reinisch et al. (2010), were interested in understanding the role of suprasegmental lexical stress information in word recognition. In a printed-word version of the paradigm, Dutch participants were presented with pairs of semantically unrelated words, which were segmentally identical for the first two syllables, but, crucially, presented a different primary stress location (e.g., *October* vs *octopus*); together with the critical word pairs, two dissimilar distractors (e.g., *dialect*, *dialogue*) were displayed on the screen. Participants' eye movements were recorded while they were given spoken instructions (e.g., *Click on the word octopus*). Eye movement analysis showed that participants' fixations on the target word (e.g., *octopus*) were more frequent than fixations on the segmentally overlapping but differently stressed word competitor (e.g., *October*) significantly before that participants could exploit segmental information in order to disambiguate the two words. Given this pattern of findings, Reinisch et al. (2010) concludes that listeners take advantage of lexical stress information for word recognition as soon as this information becomes available in the speech stream. In line with Allopenna et al. (1998), the authors provided further evidence for an incremental processing of phonetic segmental and suprasegmental information during the unfolding of the linguistic input.

All in all, these studies have shown the listener's sensitivity to different types of phonetic segmental and suprasegmental cues, which can modulate lexical activation and word recognition during spoken language comprehension. Nevertheless, Huettig et al. (2011) observed that subtle phonetic effects as rhyme competition (Allopenna et al. 1998) might be the consequence of the pre-activation of the corresponding lexical candidates, primed by the view of the objects depicted in the visual scene. Once that this pre-activation occurs, it would become much easier for the parser to detect specific phonetic cues from the linguistic input, and exploit them during language comprehension. The same holds for the printed-word version of the paradigm (Reinisch et al. 2010), as it is known that the reading of printed words rapidly activates the corresponding phonological forms (Van Orden et al. 1988; Frost 1999): consequently, also in this case it might be easier for the listener to exploit specific suprasegmental cues in the linguistic input in order to disambiguate between possible lexical candidates very early. Therefore, it might be that lexical activation of word candidates is not driven by phonemic cues, but quite the opposite: the pre-activation of word candidates, elicited by the visual scene, might make the parser more sensitive to the recognition of phonetic cues during spoken word processing. As we will see throughout the chapter, issues of lexical activation, and consequently of lexical interference, are intrinsically related to the visual nature of the paradigm. For this reason, these lexical aspects will be taken into consideration in the elaboration of the experimental design of our visual world study in chapter 4.

The topic of lexical activation has been a matter of debate also in visual world studies on bilingualism. One of the main questions addressed by bilingual studies is whether lexical access is restricted to the language in use or, conversely, both the languages are active during language processing, and can affect lexical activation accordingly. One of the most relevant visual world studies in this research area was conducted by Spivey and Marian (1999) with late Russian-English fluent bilinguals. Participants were presented with spoken Russian sentences such as *Put the stamp below the cross*.[61] The Russian word for *stamp* (i.e., *marku*) shares some initial phonetic features with the English word *marker*: significantly, the picture of a marker was one of the four objects displayed in the visual scenario, together with the picture of a stamp, and two unrelated distractors, whose names did not present any phonetic similarity with the target word, neither in the English nor in the Russian version. Results from eye movement analysis showed that, when hearing the Russian word *marku*, participants looked more often at the picture of a marker than at the pictures of the other unrelated objects. Despite being in a Russian monolingual situation, participants' visual attention was initially captured by the distractor whose English name shared some initial phonetic features with the spoken Russian word. This has led Spivey and Marian (1999) to assume that bilingual listeners are not able to deactivate the mental lexicon of the irrelevant language during word recognition in a monolingual situation (see also Marian & Spivey 2003a, 2003b).

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[61] A mirror-image version of the experiment was also conducted with English instructions, which reported resembling results

Nevertheless, more recent visual world studies have found evidence suggesting instead that lexical activation may be language-specific. Weber and Cutler (2004) presented native Dutch listeners with spoken English instructions such as *Click on the kitten*. *Now put it on the top of the diamond*, and a four-object visual display including the pictures of the target object (e.g., a kitten), an object whose Dutch name phonemically overlapped with the onset of the target word in English (e.g., a chest, *kist* in Dutch), and two phonologically unrelated objects (e.g., a flower and a swing). The authors found no evidence that Dutch listeners activated the Dutch competitor *kist* while listening to the English sentences, as they did not fixate the picture of a chest more than the other unrelated distractors after the onset of the English target word kitten. This experimental evidence is clearly at odds with previous findings by Spivey and Marian (1999), as here the native lexicon seems not to be activated during second language processing.[62]

In addition, Canseco-Gonzalez et al. (2010) reported only a weak cross-linguistic effect of lexical activation, which was modulated by the age of acquisition of the second language. They presented three groups of English-Spanish bilinguals with spoken English instructions as *Click on the beans*, and a three-object visual display including the picture of a target object (e.g., beans), a cross-linguistic cohort competitor, whose Spanish onset phonemically overlapped with that of the target word in English (e.g., moustaches, *bigote* in Spanish), and an unrelated object (e.g., a cone).[63] The eye movement analysis showed that only early bilinguals were more attracted by the picture of the cross-linguistic cohort competitor (e.g., moustaches) than by the picture of the unrelated object (e.g., a cone). This provides evidence of little cross-linguistic activation of lexical candidates in monolingual contexts of utterance, which is nevertheless significantly influenced by the age of acquisition of the non-contextual language.

Taken together, these findings indicate that several factors can determine to what degree bilingual listeners activate the lexicon of the other language in a monolingual situation of sentence comprehension: the age of acquisition of the second language, speaker's proficiency in each of the two languages, the visual

[62] It is however worth mentioning that the two bilingual populations tested by Spivey & Marian (1999) and Weber & Cutler (2004) had different linguistic backgrounds. While Russian-English speakers had immigrated to the US many years before, and were hence completely immersed in an English linguistic environment, Dutch-English speakers lived in the Netherlands, and used Dutch for everyday communication.

[63] In one experimental condition, the picture of the cross-linguistic cohort competitor has been replaced by an object whose name in English (e.g., beetle) shared some onset phonetic features with the English target word (e.g., beans). Results showed a strong within-language cohort effect across all the three groups of bilinguals, including those who acquired English in adult life. This suggests that even when they are immersed in a second language environment, bilinguals activate all plausible lexical candidates in that specific language during word recognition, based on the phonological information provided in real-time by the spoken linguistic input.

context provided in the experimental session, and fine-grained acoustic information (Weber & Cutler 2004). Furthermore, this pattern of findings is in line with an interactive view of language comprehension, according to which the process of lexical activation is constantly influenced by different sources of information (Marslen-Wilson & Tyler 1980; McClelland & Elman 1986; Allopenna et al. 1998).

A large number of word-level visual studies have investigated another key issue of language processing, that is how linguistic representations, accessed from the hearing input, and perceptual representations, accessed from the visual scenario, are integrated during spoken language comprehension. One of the main questions addressed by researchers is whether language-mediated eye movements are driven by specific similarities between the target and the competitors or by a general categorical knowledge.

In his pioneering study, Cooper (1974) was the first to observe how eye movements were connected to the word semantics from the speech input: upon hearing the word *Africa*, participants were more likely to fixate pictures of African animals (e.g., a lion or a zebra) than semantically unrelated pictures. However, it remained unclear whether this alleged semantic effect was due to a real semantic similarity between the two words or rather to a generic association, as the semantic and the associative relatedness between the target word and the visual stimuli was not controlled[64].

The issue has been further investigated in Huettig and Altmann's (2005) follow-up work (but see also Yee & Sedivy 2006; Huettig et al. 2006; Dunabeitia et al. 2009). In this eye-tracking study, participants were simultaneously presented with a sentence such as (5) and a visual display consisting of black and white drawings of four items: the target object (e.g., a piano), mentioned in the spoken input, a competitor object (e.g., a trumpet), and two unrelated distractors (e.g., a carrot and a hammer). Note that the competitor object belongs to the same semantic category of the target object (i.e., they are both musical instruments) but, crucially, the two objects are not associatively related[65].

[64] Associative relatedness is defined as the probability that one word will call to mind a second word (Postman & Keppel, 1970). An associative relation is assumed to reflect word use rather than word meaning, whereas semantic relatedness reflects the conceptual similarity or the overlap in featural descriptions of two words (Thompson-Schill et al. 1998). It is possible for words to be either weakly associated but semantically related (e.g., radish/beets) or highly associated but semantically unrelated (e.g., coat/rack).

[65] In Huettig & Altmann (2005), none of the semantic competitors were associates of the target word: the authors rejected any pairs of objects provided by the Nelson word association norms (Nelson et al. 1998), for which the participants in those norms produced the competitor after the target and vice versa.

(5) Eventually, the man agreed hesitantly, but then he looked at the *piano* and appreciated that is was beautiful

Results from the eye movement analysis revealed that, upon hearing the target word *piano*, participants directed their visual attention more consistently towards the trumpet than towards the other unrelated distractors, such as the carrot and the hammer. It seems therefore that hearing the target word *piano* has activated the semantic properties which the piano and the competitor trumpet have in common (i.e., being musical instruments): this retrieval of overlapping semantic properties has caused, in turn, the activation of the mental representation of the semantic competitor, resulting in more fixations towards the trumpet than towards semantically unrelated, and hence not mentally activated, distractors. Taken together, these data confirm that increased visual attention towards semantically related items is driven by overlapping semantic properties between the two objects rather than by a mere associative relation. Furthermore, these findings provide strong evidence of a semantic/conceptual overlap in language processing, as language-mediated eye movements seem to be driven by semantic similarities between visual and linguistic elements.

A quite intuitively related question is whether these language-mediated eye movements are also affected by perceptual properties of the objects displayed in the visual scene. In this respect, several visual studies have found that the listeners' eye gaze is often directed towards pictures of objects which share some visual properties with the target (e.g., colour, shape) but are semantically unrelated to it. (Huettig & Altmann 2004, 2007: Dahan & Tanenhaus 2005; Yee et al. 2009; Huettig & Altmann 2011; Rommers et al., 2012). In Dahan and Tanenhaus (2005), participants were simultaneously presented with a four-object visual display and a spoken instruction such as *Click on the snake*. The visual scene included the following pictures: the target referent (e.g., a snake), a competitor sharing some visual features with the conceptual representation of the referent (e.g., a rope)[66], and two unrelated distractors (e.g., an umbrella and a couch). Eye movement recordings showed that, upon hearing the word *snake*, participants looked more at the picture of a cable, which had a similar shape, than at the other distractors. Significantly, this shift in the listeners' over attention occurred even despite the visual scene displaying for about five seconds before the onset of the target word, thus providing participants with enough time to recognize the objects on the screen.

Similar findings have been reported by Huettig & Altmann (2004), who investigated whether eye movements can be affected by perceptual properties other

[66] To rule out possible phonological effects (e.g., cohort competition), the name of the visual competitor (e.g., rope) never began with the same phonological onset of the target object (e.g., snake).

than shape, such as colour. Participants heard sentences such as (6) while looking at a visual scene consisting of four coloured pictures, which were conceptually unrelated to the target word *frog* mentioned in the spoken input: a lettuce, a mitten, a pipe, and a suitcase. Note that the lettuce and the frog share a prototypical colour feature (i.e., green), thus making the picture of a lettuce a colour competitor of the target item.

(6) The boy turned around carefully, and then he saw the *frog* and looked happy

Again, results showed that, after the onset of the target word *frog*, participants made more saccades towards the colour competitor (i.e., the lettuce) than towards the other distractors. Given these results, the authors assumed that hearing the target word *frog* leads to the mental activation not only of semantic but also of perceptual properties of the corresponding object. The retrieval of this perceptual information causes, in turn, the activation of stored mental representations of elements sharing such perceptual features, resulting in more fixations towards the picture of a green lettuce than towards perceptually unrelated distractors.

Taken together, these findings provide strong evidence that visual attention is also affected by perceptual overlapping properties between the target word and possible competitors presented in the visual scene. However, it is worth noting that, if on the one hand the colour or the shape of an object can be perceived from the visual scene (i.e., perceptual information), on the other these perceptual features can also be intended as stored semantic/conceptual information about the object itself. The form of a snake, or the colour of a frog, are stored prototypical properties of the object which, besides being perceived in the visual environment, can be drawn by the listener's prior world knowledge. The shifts in overt visual attention driven by perceptual properties found in these studies must hence be interpreted with caution (Yee et al. 2009). In this respect, Huettig and Altmann (2011) investigated the effect of surface colour (i.e., the perceived but non-prototypical colour of an object) in absence of stored colour knowledge. Interestingly, they found that upon hearing a target word associated with a prototypical colour (e.g., peas), participants consistently shifted their overt attention towards any object with the same surface colour, even though this object was not prototypically associated with the colour itself (e.g., a green blouse). These results suggest that language-mediated eye movements are strictly connected to surface perceptual attributes of the visual objects rather than to stored prototypical colour knowledge (see Huettig et al. 2011 for a more detailed review).

Overt visual attention seems hence to be driven by different types of information provided by the visual context, such as semantic and perceptual properties of the depicted objects. It remains however unclear how the attentional system integrates semantic and perceptual knowledge, obtained from visual-derived representations, with language-derived representations during spoken language comprehension.

Huettig and Altmann (2011) found evidence that some types of knowledge are prioritized by the attentional system: when the visual display included both a surface colour competitor and a semantic competitor of a given target word, participants started to look at the surface colour competitor 400ms later than in the experimental condition where the surface colour competitor was the only related object in the visual scene. This suggests that the integration of semantic properties is prioritized with respect to the integration of perceptual surface attributes of the depicted objects.

To conclude, the visual world studies discussed so far have shown that listeners make use of perceptual and semantic information about the objects in the visual scene during the real-time integration of the visual and the linguistic input. However, it is possible that lexical access affects this integration, as viewing the visual scene can allow listeners to rapidly access the names of the depicted objects. The effect of lexical activation has been already addressed previously in this chapter, as concerns the listener's sensitivity to different types of phonetic segmental and suprasegmental cues in word recognition (Allopenna et al. 1998; Reinisch et al. 2010), which might be biased by the pre-activation of the corresponding lexical candidates from the visual scene. A series of findings reported by Huettig and McQueen (2007) provides further support for this hypothesis. When the visual scenario was presented about three seconds before the onset of the target word, results showed that participants looked at the phonological competitor (e.g., beaver) of the spoken target word (e.g., beaker) before they looked at the semantic (e.g., fork) and the perceptual (e.g., bobbin) competitors. However, when the same visual display was presented only 200ms before the onset of the target word, no effects of phonological competition were reported, with participants fixating all the distractors in equal measure. According to the authors, initial fixations to the phonological competitor indicated that participants had already accessed the corresponding lexical items before hearing the target word. Conversely, this early lexical access was not possible in the 200ms preview condition, as the listeners did not have enough time to retrieve the pictures' names.

In this section, we have seen that the listener can retrieve phonological, semantic, and perceptual features, either from the objects depicted in the visual scene or from the speech signal, to integrate linguistic and non-linguistic sources of information during the real-time process of spoken language comprehension. Language-mediated eye movements seem thus to be affected by the type of information and the competitors provided in the visual scene, the unfolding of the linguistic input, and the linguistic context of utterance. Nevertheless, the reported findings have underlined a crucial aspect of visual world research: the time-course of fixations and saccades to the objects displayed in the visual scene must be interpreted with caution, as they might be biased by different features of the visual scenario, and, hence, at least in some cases, they might not reflect the real-time activation of the corresponding representations.

Of particular relevance for the aim of the present study is the issue concerning the activation and subsequent retrieval of lexical information from the visual scene, primed by the view of the depicted objects, which can affect language-mediated eye movements and the mapping between the visual and the spoken input. In addition, we have seen that superficial perceptual properties of the visual objects such as colour can determine shifts in the listener's overt visual attention. These aspects are intrinsically related to the visual nature of the paradigm, and, as we will discuss in §3.4, they must be taken into consideration when deciding to investigate linguistic phenomena such as language processing using this experimental paradigm.

3.2.3.2 Language comprehension at sentence level

Traditionally, psycholinguistic research on sentence processing has largely employed classical experimental paradigms of language comprehension, which mainly rely on the evaluation of response choices and reaction times during the performance of metalinguistic judgements concerning the truthfulness of the test sentences against a visual scenario or the listener's prior world knowledge (e.g., sentence picture verification task). In such an experimental configuration, visual stimuli are treated as simple experimental features, without considering how, and to what extent, these perceptual sources of information can affect the sentence processing itself. Tanenhaus et al. (1995) was one of the first psycholinguistic studies to investigate how listeners exploit visual information during spoken language comprehension in order to disambiguate sentence structure. This pioneering work inaugurated one of the main lines of research for visual world studies dealing with language comprehension at sentence level, namely the investigation of how linguistic and visual information is integrated during the real-time comprehension process.

In this section, we will outline the two main contrasting theoretical views on how this integration of different types of information occurs, discussing some of the most relevant experimental findings reported so far. A closely related field of research concerns the phenomenon of *predictive understanding*, which occurs when language users are able to retrieve upcoming relevant linguistic information before that this is actually encountered in the linguistic input. In this respect, a large number of visual world studies have investigated how linguistic and visual information is exploited by language users to predict the upcoming linguistic input, and, crucially, how this affects language-mediated eye movements. Some of the most relevant studies will be reported. As we have seen in §3.2.3.1, the question of how language- and visually-derived representations are integrated during spoken language comprehension, as well as how linguistic (e.g., phonological) and perceptual cues can affect spoken word recognition and lexical activation, has been of central interest also for visual world studies on language processing at word level. Throughout this chapter we will see how these key issues can shed light also on some core aspects of real-time sentence processing.

Over the last few decades, a considerable amount of psycholinguistic research has been dealing with the issue of how language users integrate different types of information during spoken language comprehension. In this regard, two main theoretical views can be distinguished. Structural accounts of language processing assume that, initially, sentence processing exclusively relies on the parsing of the syntactic information, with other types of relevant information (e.g., lexical or pragmatic) being integrated only at a later stage in the comprehension process (Frazier 1979; 1987). In the following years, this two-stage view of sentence processing gained further support from the development of the notion of *modularism* (Fodor 1983), according to which different types of information are processed sequentially and independently form one another (see §3.1). Instead, interactive theories of language processing claim that different types of non-syntactic information can immediately affect the listener's initial parsing of a sentence (Tyler & Marslen-Wilson 1977). In particular, the so-called *constraint-based theories* assume that syntactic processing involves the satisfaction of multiple constraints occurring at lexical, structural and discourse level (MacDonald et al. 1994; Trueswell et al. 1994; McRae et al. 1998), and, significantly, lexical constraints (e.g., argument structure preferences) affect syntactic parsing more than the others (Snedeker & Trueswell 2004).

As discussed in detail in §3.1, Tanenhaus et al. (1995) was the first visual world study to report strong evidence in support of an interactive view of language processing, demonstrating that visual contextual cues are integrated in the syntactic processing as the linguistic input unfolds, and, crucially, they can affect spoken language comprehension and the real-time resolution of temporary syntactic ambiguities. From then on, a large number of visual world studies have provided further evidence for constraint-based accounts of sentence processing. A follow-up study of Tanenhaus et al. (1995) was conducted by Trueswell et al. (1999), who tested English-speaking adults and five-year-old children in order to investigate the effects of visual contextual information on the resolution of temporary syntactic ambiguity. Similarly to Tanenhaus et al. (1995) participants were presented with two types of sentences, that could be either ambiguous (7) or not (8) between two possible interpretations.

(7) Put the frog on the napkin in the box
(8) Put the frog that's on the napkin in the box

If in (7) the PP *on the napkin* is ambiguous between being a modifier phrase of the DP *the frog* and indicating the destination of the action described in the VP, in (8) the presence of a complementizer (i.e., *that*) forces the former interpretation of the

PP itself, deleting the temporary ambiguity of the syntactic structure. While listening to these spoken instructions, participants were presented with two types of visual scenarios, supporting one of the possible interpretations of the ambiguous sentence. The two-referent context contained two identical frogs (one on a table and one on a napkin) which were both possible referents of the target sentence, and two other objects (e.g., an empty napkin and an empty box) representing the incorrect (e.g., a napkin) and the correct destination (e.g., a box) of the action. Instead, in the one-referent context the frog placed on the table was replaced by another animal (e.g., a horse), making the referent of the target sentence univocal and, therefore, any further modification of the DP *the frog* redundant.

The eye movement analysis showed different patterns of fixations between the two groups of subjects, suggesting that children and adults process temporary syntactic ambiguity differently. On the one hand, the group of adults replicated the context effect found always with adults by Tanenhaus et al. (1995): in the one-referent contexts they initially interpreted the PP *on the napkin* as destination place of the action, as indicated by an initial increase of fixations towards the incorrect destination (i.e., the empty napkin) shortly after hearing *on the napkin*, and by a delayed shift of visual attention towards the box; no significant patterns of fixations towards the incorrect destination were found instead in the two-referent context. On the other hand, children were more likely to initially look at the incorrect destination (i.e., the empty napkin) in both the referent-contexts. This pattern of findings clearly indicates that, if adults are able to exploit and integrate contextual and discourse information from the earliest stages of the syntactic processing, and to revise initial incorrect interpretations, five-year-old children instead do not take into account these non-syntactic constraints when they process the sentences, mainly relying on local syntactic factors, and showing little ability to revise the initial interpretation provided. Although it seems that children fail to integrate visual contextual information during the syntactic processing, Trueswell and Gleitman (2004) claim that this can be attributed to the fact that such cues tend to be less reliable and robust than the syntactic ones: as a consequence, children would simply need more time to understand the usefulness of contextual cues and to exploit them during sentence comprehension.

In a subsequent work, Snedeker and Trueswell (2004) provide further evidence in support of a multiple-constraint satisfaction during sentence processing, drawing particular attention to the central role played by lexical cues in the parsing. English-speaking adults and five-year-old children were presented with three types of spoken sentences containing an ambiguous prepositional phrase, which could be attached either to the VP, indicating the tool employed to perform the action described by the verb, or to the DP, specifying an additional property of the mentioned entity. Three types of verbs were compared: verbs frequently accompanied by an instrumental PP (instrumental condition- (11)), verbs rarely accompanied by an instrumental PP (modifier condition- (9)), and verbs which are normally accompanied by different types of prepositional phrases (neutral condition -(10)). Note that, differently from previous comprehension studies (e.g., Tanenhaus et al. 1995; Trueswell et al. 1999), the test sentences were globally rather than temporary ambiguous, as the PP-attachment ambiguity did not resolve itself with the unfolding of the linguistic input: this manipulation was introduced because the authors hypothesized that, in previous experiments, children might have failed in resolving the syntactic ambiguity because they were confused by the use of too complex and uncommon sentence types, characterized by the occurrence of the disambiguating PP immediately after the introduction of the ambiguous one.

(9) Choose the cow with the stick (modifier condition)
(10) Feel the frog with the feather (neutral condition)
(11) Tickle the pig with the fan (instrument condition)

While listening to these spoken instructions, participants were presented with two types of workspace. In the one-referent context, the following set of objects was displayed: a target instrument which can be used to carry out the action described by the verb (e.g., a stick in (9)), a target animal carrying in turn a small version of the target instrument (e.g., a cow carrying a stick), a distractor instrument (e.g., a candle) a distractor animal carrying a small version of the distractor instrument (e.g., a giraffe carrying a candle). In the two-referent context, the distractor animal and the target animal were of the same kind (e.g., two cows carrying the former a candle and the latter a stick, respectively).

The eye movement analysis for the group of adults showed that, after the onset of the ambiguous PP, an increase of fixations towards the target instrument was found in the instrument condition (11) but not in the modifier one (9) - regardless of the referent-context. Immediately after the DP onset, participants in all the one-referent contexts were consistently looking at the target animal, while they were paying equal attention at the two identical animals in all the two-referent contexts: this pattern of looks clearly indicates that they have used lexical information to rule out the distractor animal. In the two-referent context, when the verb did not provide any lexical cue for an instrument interpretation of the prepositional phrase (i.e., modifier and neutral verb conditions), participants rapidly abandoned the distractor animal and focused their gaze on the target one after hearing the PP, indicating that they have interpreted it as a restrictive modifier of the DP. Instead, in the instrument condition, participants' looks at the distractor animal continued until the end of the trial, suggesting that they were still evaluating the two possible interpretations of the ambiguous PP. Likewise adults, children's patterns of fixations were strongly influenced by the type of lexical verb, with significantly more looks towards the target instrument in the instrument condition than in the modifier one: this occurred independently of the number of referents present in the visual context. After the onset of the ambiguous PP, children took advantage of the lexical information provided by the DP and directed their gaze towards the target animal in all the one-referent contexts. Instead, in the two-referent context, children's looking pattern behaviour was significantly affected by verb type. When the verb did not provide any lexical cues for an instrument interpretation of the PP, children immediately shifted their visual attention towards the target animal, providing, likewise adults, a modifier interpretation of the prepositional phrase. Conversely, in the instrument condition, they continued to look at both the possible referents until the end of the trial: moreover, some of the children asked to the experimenter on which animal they should perform the action described in the sentence. This clearly indicates that children struggled to resolve the syntactic ambiguity by analysing the PP as modifier when the lexical properties of the verb encouraged instead an instrument interpretation.

Taken together, these findings support a constraint-based account of language processing, providing evidence that multiple sources of information, such as lexical and visual contextual cues, are used by the parser to guide an incremental interpretation of the sentence. Moreover, the results suggest that the sensitivity to different constraints develop over time: adults are able to combine lexical and contextual information to solve syntactic ambiguity; instead, results indicate that children exclusively rely on lexical verb bias during sentence interpretation: however, patterns of fixations reveal an emerging sensitivity also to referential constraints. This clearly indicates that lexical constraints affect parsing preferences more robustly than contextual and discourse constraints, by emerging even earlier in the development.

The role of contextual constraints during sentence comprehension has been further investigated by Chambers et al. (2004), who examined to what extent perceptual and action-based knowledge can affect syntactic parsing in adults. Similarly to Tanenhaus et al. (1995), English-speaking participants were presented with spoken instructions either containing (12) or not (13) temporary syntactic ambiguity. In the meantime, participants were presented with two types of visual scenarios, supporting one of the possible interpretations of the ambiguous PP in the bowl in (12). Each version of the visual scenario contained four objects: a target referent (e.g., egg in a bowl), a referential competitor (e.g., egg in a glass), the correct destination (e.g., flour), and the incorrect destination (e.g., an empty bowl). Note that, differently from previous comprehension studies (Tanenhaus et al. 1995; Trueswell et al. 1999; Snedeker & Trueswell 2004), what changes across the two versions of the visual scenario was not the item depicted as competitor but rather a perceptual property of the target item itself: while in one of the two visual contexts, both the eggs are presented in liquid form (compatible competitor condition), and hence are compatible with the action of pouring, in the other, one of the eggs is solid (incompatible competitor condition).

(12) Pour the egg in the bowl over the flour
(13) Pour the egg that's in the bowl over the flour

The analysis of the eye movement patterns showed that in the compatible competitor condition with ambiguous instructions, participants immediately looked at the target referent (e.g., the egg in a bowl) after hearing the ambiguous PP, with very few saccades towards the incorrect destination (e.g., the empty bowl). In contrast, in the incompatible competitor condition, after the onset of the PP in the bowl, participants fixated more steadily the incorrect destination (e.g., the empty bowl), and they shifted their attention towards the target referent (e.g., the egg in the bowl) only after the offset of the final PP. Significantly, these fixations towards the incorrect destination were not reported with unambiguous instructions (13). These findings clearly indicate that non-linguistic perceptual[67] constraints can influence sentence processing from the earliest moments of syntactic ambiguity resolution, which seems to involve the parser's evaluation of specific action-based affordances that can affect the accomplishment of the action required by the instruction.

On the one hand visual research on language comprehension has provided consistent evidence that linguistic and visual sources of information are integrated during real-time sentence processing; on the other hand a question that has remained open is whether language users can exploit these different types of information to predict and retrieve the upcoming relevant linguistic information before that it was actually encountered in the speech signal. The issue of *predictive understanding* has been extensively investigated by Altmann and colleagues, who conducted a series of visual world studies to investigate how, and when, linguistic information is integrated with perceptual information retrieved by the visual context, and how this integration affects language-mediated eye movements (Altmann & Kamide 1999; Kamide et al. 2003; Kamide, Altmann et al. 2003; Altmann & Kamide 2007; Altmann & Kamide 2009). In their first eye-tracking study, Altmann & Kamide (1999) who employed semi-realistic visual scenes to

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[67] It may be argued that action-based constraints influencing the syntactic parsing might have been triggered by the lexical information encoded by the verb *to pour*, which requires the theme to be in liquid form. To rule out the possibility that the reported action-based effect is semantic in nature, requiring hence only a minimal access to non-linguistic perceptual information, Chambers et al. (2004) conducted a second version of the experiment, in which the semantic of the verb could not determine which one of the two competitor items in the visual scenario must be used to complete the action evoked in the linguistic input (e.g., *Put the whistle on the folder in the box*). Significantly, patterns of fixations resembled that of the first experiment, with a consistent number of fixations towards the incorrect destination only in the condition in which the competitor was not compatible with the accomplishment of the action (e.g., a whistle with no string). This further corroborates the assumption that syntactic processing is influenced by the listener's evaluation of non-linguistic contextual and action-based constraints.

investigate whether the semantic information conveyed by the verb is exploited by the listeners to retrieve upcoming relevant linguistic information. While listening to sentences such as (14) and (15), participants were presented with a visual scene depicting a young boy surrounded by different items: a toy train set, a toy car, a birthday cake, and a balloon (see Figure 3.3 in §3.2.1). Note that the lexical information provided by the verb *to eat* in sentence (15) restricted the number of possible referents of the action described by the VP to one, as the cake was the only edible object in the scene. Conversely, in sentence (14), all the four objects were possible target referents of the verb *to move*.

(14) The boy will move the cake
(15) The boy will eat the cake

The eye movement analysis showed that saccadic movements towards the target object (i.e., the cake) started significantly earlier when participants heard the sentence containing the verb *to eat* than the sentence containing the verb *to move*. In the eat-condition, participants' looks at the target object started to increase between the offset of the verb and the onset of the DP *the cake*; in the move-condition, instead, looks at the target object started only after the onset of the DP. This pattern of anticipatory eye movements in the eat-condition provides strong evidence that semantic information conveyed by the verb can be used to anticipate an upcoming theme, by guiding visual attention towards those objects in the visual context which satisfy the selectional restrictions of the lexical verb. Crucially, visual information from the real-world context is integrated in the linguistic input before the onset of the spoken word referring to the target object, and, hence, before that its semantic properties become available in the speech stream. This suggests that sentence processing is characterized by a predictive relationship between verb-specific knowledge and the visual context of utterance.

In a subsequent study, Kamide et al. (2003) examined whether the anticipatory eye movement effects reported in Altmann & Kamide (1999) are driven exclusively by the semantic information extracted at the verb, or whether the upcoming theme can also be anticipated by the combination of verb information and its grammatical subject (i.e., agent). While listening to English sentences such as (16) and (17), participants were presented with a semi-realistic visual representation of a fairground, depicting a man, a young girl, a motorbike, and a carousel. Unlike in Altmann & Kamide (1999), both the motorbike and the carousel satisfy the selectional restrictions of the verb *to ride*, and are hence eligible as possible themes of the action described by the VP; similarly, both the girl and the man are plausible agents of the action of riding. Nevertheless, the listener's encyclopaedic world knowledge suggests that the little girl is more likely to ride a carousel than a motorbike, while the opposite holds for the man.

(16) The man will ride the motorbike

(17) The girl will ride the carousel

Eye movement analysis showed an increase of anticipatory fixations to the motorbike when participants heard sentence (16), and to the carousel when they heard instead sentence (17). In other words, before the onset of the post-verbal grammatical object (i.e., theme), participants had already started to look at the motorbike when the man was the agent of the action of riding, and at the carousel when the agent was instead the little girl. This evidence clearly indicates that the upcoming relevant linguistic information can also be predicted by the combination of agent and verb semantics and by verb selectional restrictions. This combinatory linguistic information significantly affects anticipatory eye movements towards appropriate referents in the visual context, which satisfy the selected semantic features, even before that the semantic properties of the theme become available in the linguistic input.

Nevertheless, Altmann and Kamide (2009) showed that eye movement effects are not only driven by specific properties of the visual scene and linguistic input, but they also reflect dynamically mental representations that the listener is continuously updating during the real-time processing of both linguistic and visual stimuli. In Altmann and Kamide (2009), participants were presented with a semi-realistic visual scene, such as shown in Figure 3.7. In the meantime, they heard a target sentence such as (20), preceded by two possible linguistic contexts describing how one of the objects (e.g., the glass) was going to be moved (18) or not (19) by the woman to a new location (e.g., the table).

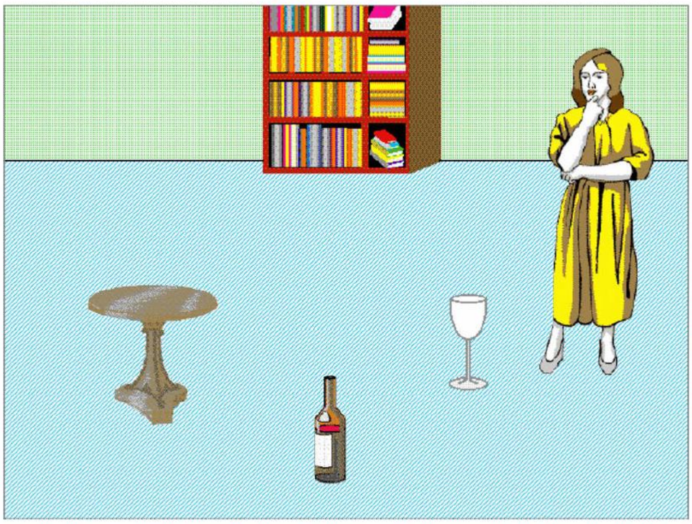

Figure 3.7. Example of visual scenario in Altmann & Kamide (2009)

(18) The woman will put the glass on the table (moved condition)
(19) The woman is too lazy to put the glass on the table (unmoved condition)
(20) The woman will pick up the bottle and pour the wine carefully into the glass

The configuration of the visual scenario remained unchanged across conditions, but its mental representation was manipulated by means of the contextualizing sentence: while the mental location of the glass changed from the floor to the table in (18), it remained the same in (19). Eye movement results showed that after hearing the verb *pour*, participants started to look consistently at the location of the glass determined by the contextual utterance rather than at its actual location in the visual scene, as indicated by increasing fixations towards the table and not towards the floor only in the *moved condition*. Taken together, these data suggest that language-mediated eye movements reflect the real-time mapping of the linguistic input onto continuously updated and context-determined mental representations of the visual scene and the depicted objects.

To conclude, the visual world studies discussed in this section strongly support constraint-based theories of sentence processing, providing compelling evidence that different types of linguistic and non-linguistic information can immediately affect syntactic processing, which involves the satisfaction of multiple constraints occurring at lexical, structural and discourse level: in particular, lexical restrictions are considered to robustly affect parsing preferences, emerging even earlier than other constraints during the development. These results speak in favour of an incremental view of sentence processing, as the parser makes use of non-syntactic information as soon as it is encountered in the unfolding linguistic input and in the visual context in order to guide the real-time process of language comprehension. Interestingly, studies on language comprehension focusing on word level have reported similar consideration. In §3.2.3.1 we have seen how the listener can retrieve phonological, semantic and perceptual features, either form the speech stream or from the visual scene, to incrementally integrate linguistic and non-linguistic information during spoken word recognition. Therefore, at both these levels of language comprehension, the initial parsing seems not to be exclusively based on syntactic information, as assumed by structural accounts of language processing (Frazier 1979; 1987), but, rather, it appears to be sensitive to other types of linguistic (e.g., lexical, phonological, pragmatical) and perceptual information from the visual scene which immediately exert their influence on the comprehension process.

Furthermore, visual world studies on predictive understanding have shown that listeners can make use of linguistic and visual information to predict upcoming relevant linguistic input before it is actually encountered in the unfolding speech stream. Researchers have provided compelling evidence that semantic and lexical information conveyed by the verb, as well as by the combination of agent and verb semantics, and verbal selectional restrictions affect language-mediated eye movements, resulting in patterns of anticipatory fixations towards plausible referents in the visual scene before the onset of the corresponding spoken word. Significantly, language-mediated eye movements do not simply reflect the integration of linguistic information from the spoken sentence with perceptual information retrieved by the visual context, but they also reflect event-related mental representations which are dynamically updated and adjusted on the basis of the information derived from both the linguistic and the visual input.

The review of visual studies on language comprehension has highlighted some core aspects of how different sources of visual and linguistic information interact during the real-time process of spoken language comprehension, but it has also brought out some intrinsic limitations of the visual world paradigm for the study of language processing. Taken together, these aspects provide a relevant theoretical background for the present study, also in terms of experimental design set-up and interpretation of the results.

3.3 Studying negation processing using the Visual World Paradigm

In chapter 2 we have seen that the processing of sentential negation has been widely investigated using classical experimental paradigms such as the sentence-picture verification task (Wason 1961; Gough 1966; Trabasso et al. 1971; Clark & Chase 1972; Carpenter & Just 1975; Kaup et al. 2006, 2007; Lüdtke et al. 2008; Giora et al. 2005; Hasson & Glucksberg 2006; Vender & Delfitto 2010). Indeed, there is little psycholinguistic research that has investigated the comprehension processes underlying negation within the visual world paradigm using the eye-tracking technology: moreover, the few visual world studies on the topic are quite recent when compared to the long tradition of studies on negation (Ferguson et al. 2008; Tian et al. 2010; Orenes et al. 2014; Orenes et al. 2015; Tian et al. 2016). Nevertheless, the visual world paradigm can provide extremely precise information on the real-time processing of sentential negation, which other traditional experimental methodologies do not offer: in particular, eye movement data can give important insights on how visual and linguistic stimuli interact during the processing of negative sentences, and to what extent the different pictures presented in the visual scene are exploited by the parser during online comprehension. This is particularly useful in order to understand whether the positive representation of the argument of negation is activated during the interpretation process: when people listen to negative sentences in a visual world configuration they are expected to look more frequently at the most active information in their working memory, as eye movements reflect interactions between linguistic and visual representations occurring at the conceptual level (Cooper 1974; Tanenhaus et al. 1995; Allopenna et al. 1998; Dahan & Tanenhaus 2005; Altmann & Kamide 2009; among others). Moreover, the analysis of the listener's looking pattern behaviour can tell us exactly when negation is integrated into sentence meaning during online comprehension, by comparing this pattern with that of the corresponding affirmative sentence. While the advantages and limitations of studying negation processing within the visual paradigm will be further discussed in §3.4, in this section we will review two studies conducted by Orenes and colleagues (2014,2015) which contribute to the broad theoretical debate on negation (chapter 2) providing insights on the processing from a visual world perspective. Particular attention will be devoted to the eye movement analyses and the resultant theoretical implications. Throughout the discussion, we will also underline some limitations of these studies as concerns the interpretation of the results and the set-up of the experimental design, which constitute the starting point for the development of the present study (chapter 4).

3.3.1 Negation processing across pragmatic contexts: Orenes et al. (2015).

Orenes et al. (2015) investigated how the pragmatic context of utterance can influence the processing of sentential negation. Spanish-speaking adults were auditorily presented with a sentence introducing a general situation (e.g., *Veronica needed a new car for work*). This was followed by a second sentence defining the linguistic context, which could be consistent (21), inconsistent (22), or neutral (23) with respect to the subsequent target affirmative (e.g., *Her dad was rich*) or negative (e.g., *Her dad was not poor*) sentence.

(21) She supposed that her dad had enough savings (consistent context)
(22) She supposed that her dad had little savings (inconsistent context)
(23) Her dad lived on the other side of the town (neutral context)

The visual scene consisted in two images displayed on the two sides of the screen, depicting a poor man and a rich man, respectively. Note that, while the picture of a rich man matched the actual situation described by the target negative sentence (e.g., *Her dad was not poor*), the picture of a poor man was consistent with the corresponding negated state of affairs. Similarly, (22) is an inconsistent context with respect to the meaning conveyed by the negative sentence, but it was consistent with the corresponding negated situation, namely the dad being poor. Each trial was structured as follows: participants listened to the general situation and linguistic context while looking at a central fixation cross on the screen; then, the visual stimuli appeared for two seconds, after which there was the onset of the target sentence. At the end of the trial, participants were asked to answer a general question concerning the situation described in the short story by pressing a yes or a no button (e.g., *Did Veronica need a new car?*). Participants' fixations were analysed in the time-window ranging from the onset of the critical adjective (i.e., *rich* in the affirmative sentence, and *poor* in the negative sentence) to 3000ms after its offset.

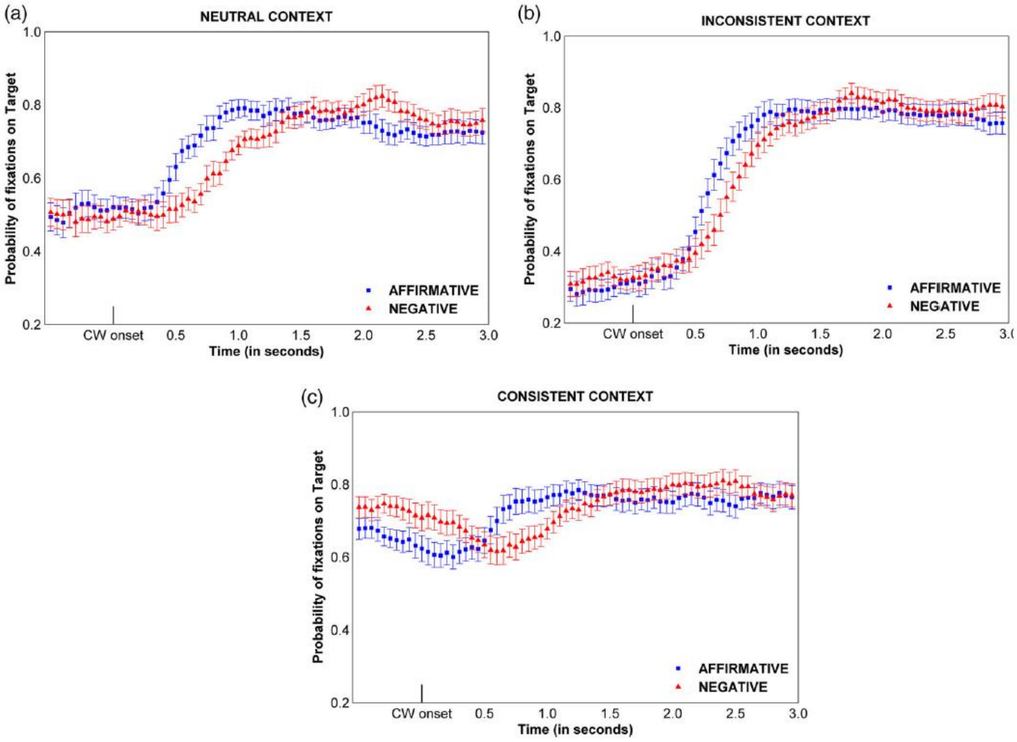

Figure 3.8. Probabilities of fixations on the target picture (the rich man) over time, for affirmative (blue) and negative (red) sentences within neutral (a), inconsistent (b), and consistent contexts (c) – from Orenes et al. (2015). Probabilities of fixations on the target picture before CW (critical word) onset for both affirmative and negative sentences: chance rate (50%) in the neutral context (a); < 40% in the inconsistent context (b); around 70% in the consistent context (c).

Results from the eye movement analysis suggest that pragmatic information can influence the way in which sentential negation is processed: in particular, negation seems to be processed faster when the negated situation has been previously provided by the linguistic context. In the neutral context (Figure 3.8a), participants' fixations on the target picture[68] (e.g., the rich man) started to increase at 500ms from the target word onset with affirmative sentences (e.g., *Her dad was rich*), and at 800ms with negative sentences (e.g., *Her dad was not poor*). This pattern resembles the classical effect of negation (Wason 1961; Carpenter & Just 1975; Kaup et al. 2006; Kaup et al. 2007), with participants being slower in target identification with negative sentences than with affirmative ones. In the inconsistent context (Figure 3.8b), which describes the negated state of affairs, the authors found

[68] Although participants are not asked to perform any explicit task (e.g., identify the picture matching the meaning of the negative sentence), hereinafter We will use the term *target picture* to refer to the picture depicting the actual state of affairs described by the negative sentence. Similarly, the term *target identification* will refer to participants fixating the picture corresponding to the semantic meaning conveyed by the negative sentence.

an increase in fixations on the target picture at 500ms from the word onset with affirmative sentences, and at 600ms with negative sentences. While affirmatives were processed similarly both in the inconsistent and the neutral contexts (500ms), negative sentences were processed faster (600ms vs 800ms) when the prior linguistic context provided the listener with the representation of the negated situation, namely the dad having little savings and hence being poor. Lastly, in the consistent context (Figure 3.8c) an increase of fixations on the target picture started at 650ms after the word onset for affirmative sentences. Interestingly, fixations for negative sentences showed a different looking pattern behaviour with respect to those reported for the negative sentences uttered in the other contexts. As a consequence of the linguistic context provided, consistent with the representation of a rich man, participants were already biased towards the target picture early on (around 70% of fixations on the target picture before the onset of the target word) both in the affirmative and the negative conditions. Nevertheless, participants shifted their visual attention from the picture of a rich man towards the picture of a poor man at 800ms after hearing the critical word when this was preceded by negation (i.e., *poor*): a new increase of fixations on the target picture started only at around 1450ms after the target word onset. According to the authors, this delay in target identification, in comparison with negative sentences in the other contexts, was a consequence of the target sentence not being very informative. While in the inconsistent and the neutral contexts the listener initially had no clue that the dad was a rich man, the consistent context already provided the listener with this information. It follows that, in such a context of utterance, the use of negation was not fully informative, since it was not used to express a deviation from a presupposition established in the discourse context (Wason 1959, 1961; Givòn 1978; Horn 1989): hence, the comprehension process might have been slowed down by participant's need to adjust the lacking contextual information, creating the corresponding positive assumption denied by the negative statement.

Taken together, these findings suggest that pragmatic information can modulate the processing of negation: if the negated situation has been previously introduced in the situational context, negative sentences are processed faster, as indicated by shorter reaction times for target picture identification (600ms vs 800ms/1450ms).

These results are in line with a pragmatic view of negation processing (§2.2.2.1): when presented in pragmatically felicitous contexts, such as the inconsistent one, negation is incrementally incorporated into sentence meaning, and its comprehension does not require too much effort compared to affirmative sentences (Wason 1959, 1961; Nieuwland and Kuperberg 2008; Dale and Duran 2011). This clearly emerges when we compare the different increases in target fixations for affirmative and negative sentences among the three linguistic contexts: in the neutral and consistent contexts the increase in fixations with negative sentences started respectively 300ms and 800ms after the increase with affirmatives; instead, in the inconsistent context, the delay of negative sentences was only 100ms compared to the affirmatives. In contrast, pragmatic appropriateness does not influence the processing of affirmative sentences: participants took almost the same time to fixate the target picture across the different linguistic contexts of utterance (500ms in neutral and inconsistent contexts; 650ms in consistent context). On the one hand pragmatic information can facilitate the comprehension of sentential negation, on the other hand the results show that negative sentences were always processed slower than affirmation, even when a pragmatically felicitous context was provided. According to the authors, this processing penalty might be due to the fact that eye movement data are extremely sensitive to subtle and context-dependent processing differences between affirmative and negative sentences, which instead might go unnoticed using other classical experimental methodologies.

While pragmatic accounts do not exclude that negation can undergo a two-stage based interpretation in pragmatic unsupportive contexts (§2.2.2.1), the results presented in Orenes et al. (2015) can also be explained by assuming that negative sentences always receive a non-incremental interpretation, regardless of the context of utterance, as assumed by the Two-Step Simulation Hypothesis (Kaup et al. 2007). As discussed in §2.2.1.3, the Two-Step Simulation Hypothesis takes into account the role of the context in negation processing: when uttered in a supportive context, which already provides the comprehender with hints for the simulation of the negated state of affairs, negative sentences are processed faster. Unlike pragmatic accounts, however, the Two-Step Simulation Hypothesis considers negation processing inherently more complex and demanding than that of affirmatives, as it always requires the construction of one extra mental simulation compared to the corresponding affirmative sentence (i.e., the representation of the negated state of affairs): supportive pragmatic contexts have hence a facilitating effect on a computation which has, in any case, a higher processing load compared to affirmatives.

Interestingly, this is exactly what Orenes et al. (2015) found in the inconsistent context: even when uttered in a pragmatic felicitous context, negative sentences displayed, nevertheless, longer reaction times for target identification, with listeners starting to fixate the target picture 100ms later compared to affirmatives (600ms vs 500ms). Moreover, the classical effect of negation reported in the neutral context can be explained accordingly. As shown in Figure 3.8a, participants took 300ms longer to start fixating the target picture with negative sentences, indicating that, unlike with affirmative sentences, they initially paid more attention to the picture of a poor man, depicting the negated state of affairs. Significantly, this is in line with what predicted by the Two-Step Simulation Hypothesis (Kaup et al. 2007): this difference in the looking pattern behaviour across sentence polarities can be explained assuming that, since the linguistic context of utterance did not provide the listener with any hints for the simulation of what would have been the negated state of affairs, participants retrieved this information later on from the visual scene, in order to simulate the first mental representation required in the comprehension process. Instead, the inconsistent linguistic context had already provided the listeners with the information that the dad had little savings: when they heard the negative sentence, participants had already constructed the mental representation of the dad being poor, by inferring it from the linguistic context: hence, they did not need to resort to the subsequent visual information provided by the visual scenario in order to simulate the negated state of affairs. As we have seen in §3.2.3.2, visual and linguistic sources of information provided by the discourse context are incrementally exploited by the parser to continuously update the mental representation of the event described by the linguistic input (Altmann & Kamide 2009; see Zwaan & Radvansky 1998 for a detailed review). Discourse context can, therefore, change aspects of the mental representations related to an unchanging visual scene by dynamically changing the situation, and such changes directly affect eye movements towards the scene as the linguistic input unfolds. Lastly, the participants' looking pattern behaviour in the consistent context can also be explained assuming a non-incremental processing of negation. If on the one hand this context was consistent with respect to the meaning conveyed by the subsequent negative sentence (i.e., the dad being rich), on the other hand it did not provide the listener with any hint for the simulation of the negated state of affairs (i.e., the dad being poor). After hearing the target word poor, participants retrieved the information needed for the elaboration of this mental simulation from the visual context, by momentarily shifting their visual attention from the target picture of a rich man (biased from the linguistic context) towards that of a poor man. Delayed fixations towards the target (1450ms) in Figure 3.8c indicate that at this point negation has been integrated into sentence meaning, and that the mental representation of the negated state of affairs has been finally modified accordingly to reflect the actual meaning of the negative sentence.

All in all, a non-incremental view of negation processing gives a convincing interpretation of the results reported by Orenes et al. (2015). Although the processing of negative sentences is generally affected by pragmatic contextual information, differences in the looking pattern behaviour compared to affirmative sentences would rather be evidence of an intrinsically more demanding processing, due to the nature of the mental simulations involved in the comprehension process.

Interestingly, the present results support previous experimental findings showing that the inhibition of the information under the scope of negation does not occur during the early moments of sentence comprehension (Kaup and Zwaan 2003; Hasson and Glucksberg 2006; Giora et al. 2007, see §2.2.2.2 for further details). This is particularly evident in the consistent context, where participants paid more attention to the picture matching the negated situation (e.g., a poor man) between 800ms and 1450ms after target word onset. This pattern of findings is consistent with the results reported, among others, by Kaup et al. (2006), who found that between 750ms and 1500ms after the onset of the negative sentence, participants were faster in the recognition of a picture matching the negated situation, whereas after 1500ms they were faster when presented with the picture matching the actual state of affairs (§2.2.1). Instead, this looking pattern behaviour was not reported in the inconsistent context, suggesting that the retainability of the negated concept can also be strongly influenced by the context of utterance and global discourse considerations. Once again, however, this pattern of findings can also be interpreted as evidence for a non-incremental processing of negation: a late inhibition of the negated meaning might correspond to the second stage of sentence comprehension, during which the simulation of the positive state of affairs is rejected and negation is integrated into sentence meaning (§2.2.1.3).

To conclude, it is worth reminding that the time-course of eye movement data must be interpreted with caution, as attentional shifts towards the objects in the visual scene might be co-determined by the real-time integration of different types of linguistic and non-linguistic information from both the visual scene and the spoken input. On the one hand, participants' looking pattern behaviour was initially biased towards the picture corresponding to the state of affairs described in the linguistic context: before the onset of the target word, participants were consistently looking at the picture of a rich man after hearing the consistent context (i.e., describing the actual state of affairs) and at the picture of a poor man after hearing the inconsistent context (i.e., describing the negated state of affairs). Instead, after hearing the neutral context, participants were looking with the same frequency at both the pictures. Participants' eye movements were hence directed towards the most active information in their working memory, reflecting - at least in the consistent and the inconsistent contexts - the activation of the corresponding mental representations. On the other hand, subsequent attentional shifts towards the picture of a poor man after the target word onset in negative sentences might not necessarily indicate the dynamic update of the mental representation of the event elicited by the linguistic context: rather, they might merely reflect the online activation process of lexical semantics that occurs automatically during the unfolding of the linguistic input (Cooper 1974; Tanenhaus et al. 1995; Allopenna et al. 1998; Huettig & Altmann 2005). Thus, we cannot exclude that language-mediated eye movements towards the picture of the negated argument do not correspond to an actual stage of the comprehension process. As we have already pointed out throughout this chapter, lexical activation effects are intrinsically related to the visual nature of the visual world paradigm, and must therefore be taken into consideration when analysing the time-course of eye movements.

3.3.2 Negation processing across verbal contexts: Orenes et al. (2014).

In another visual world study, Orenes et al. (2014) investigated whether accessing the mental representation of the actual state of affairs is a mandatory step in the comprehension process, or just one possibility. Previous studies have shown that the suppression of the information occurring under the scope of negation is affected not only by pragmatic and contextual considerations (Giora et al. 2006, 2007; Paradis & Willners 2006), but also by the types of predicates and terms involved in the negative sentence. In particular, Mayo et al. (2004) found that the suppression of the negated meaning is facilitated by the availability of a complementary concept (e.g., even/odd): when the negated term has no direct antonym (e.g., adventurous), the information occurring under the scope of negation is retained longer during the comprehension process (see §2.2.2.2 for a detailed review of the study). Similarly, Orenes et al. (2014) assumed that the availability of the alternative affirmative can affect the way in which negation is processed: to test this hypothesis, they manipulated the availability of the alternative affirmative by presenting the target sentences either in binary or multary verbal contexts.

Spanish-speaking adults were first auditorily presented with a sentence establishing the verbal context, which could be either binary (24) or multary (25). This was followed by a target sentence, which in turn could be in either an affirmative or negative polarity (26).

(24) The figure could be red or green (binary verbal context)
(25) The figure could be red, or green, or blue, or yellow (multary verbal context)
(26) The figure was/was not red

The visual scene was the same across conditions, and consisted in four coloured figures (a red, a green, a yellow and a blue one) arranged according to the typical four-object display set-up (Huettig & McQueen, 2007). One of the figures (e.g., the red one) was directly mentioned in the target sentence: while in the affirmative sentence it corresponded to the target (e.g., *The figure was red*), in the corresponding negative counterpart it represented instead the negated state of affairs (e.g., *The figure was not red*). The availability of a complementary concept for the negated term was made possible through the manipulation of the verbal context: the three remaining pictures (e.g., yellow, blue, and green figures) were all introduced in the multary context (25), but, crucially, only the green one was directly mentioned in the binary context (24). By doing so, the negated term had a corresponding alternative only in the binary verbal context, with the green figure being the target of the negative sentence; instead, target identification was not so straightforward in the multary verbal context, in which the very same green figure became only one of the three possible targets.

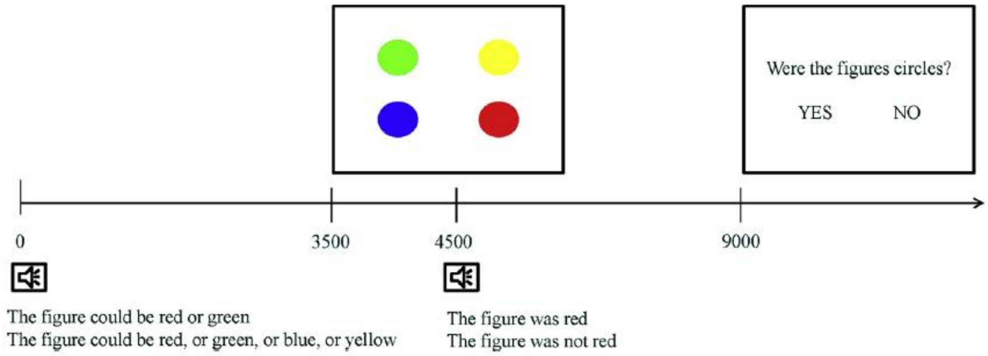

Figure 3.9. Experiment procedure and example of the visual scenario in Orenes et al. (2014)

Each trial was structured as follows: participants listened to the verbal context while looking at a central fixation dot on the screen; then, the display with the four coloured figures appeared for 5500ms: after one second of display preview there was the onset of the target sentence. At the end of the trial, a written question about the shape of the figures appeared on the screen (e.g., *Were the figures squares?*): this task was not directly related to the comprehension of the test sentences. Participants' fixations were analysed in the time-window ranging from the onset of the critical word (i.e., the colour word mentioned in the affirmative and in the negative sentence) to around 2000ms after its offset.

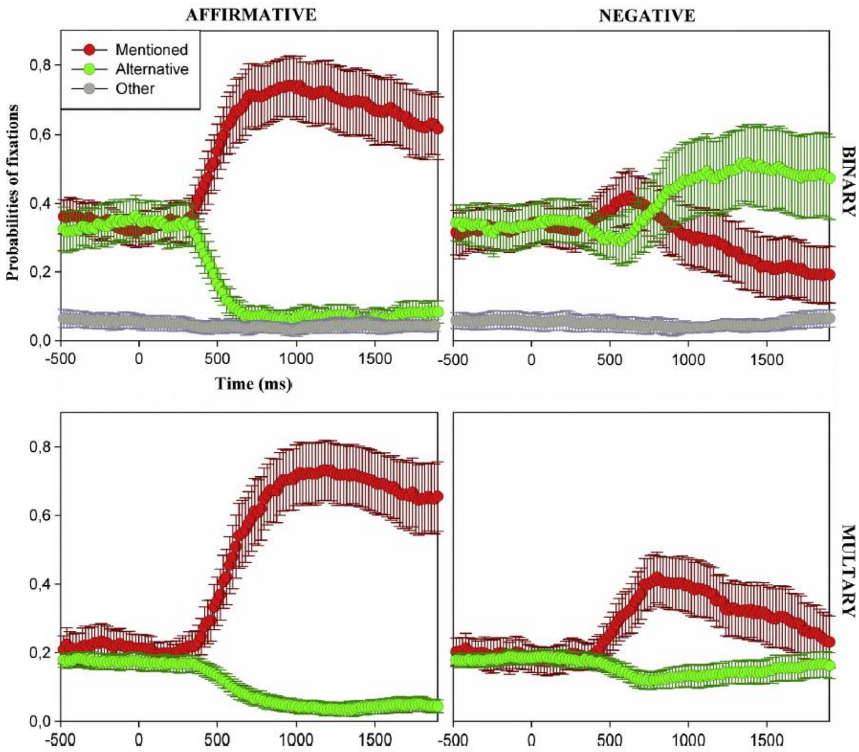

Figure 3.10. Probabilities of fixations on the mentioned colour (red line) and on the alternative colour (green line) for affirmative and negative sentences with binary (above) and multary (bottom) contexts – from Orenes et al. (2014). Time point 0ms corresponds to the onset of the critical word.

Results from eye movement analysis suggest the comprehension of negative sentence is affected by the verbal context of utterance. As shown in Figure 3.10, affirmative sentences display a similar increase of fixations on the mentioned colour in both the binary and the multary contexts: in the former, participants started to look at the mentioned colour 380ms after the target word onset, while in the latter, the increase of fixations started after 500ms. On the one hand the processing of affirmative sentences seems not to be affected by the verbal context and on the other hand the analysis of fixations for negative sentences reveal a completely different looking pattern behaviour depending on whether they were presented in a multary or in a binary context. Specifically, the temporal course of negative sentences in the multary context resembles that of affirmatives, with an immediate increase of fixations towards the mentioned colour 440ms after the target word onset: unlike in affirmative sentences, however, the mentioned colour does not correspond to the target picture but rather to the representation of the negated state of affairs (i.e., the figure being red). In the binary context, instead, after a short period of increased fixations on the mentioned colour (between 500ms and 800ms after target word onset), participants consistently fixated the alternative colour (i.e., the green picture) starting from 1340ms after the target word onset.

The authors interpreted the different pattern of fixations for negative sentences as evidence that negation can be processed in two different ways, depending on the availability of the alternative affirmative: when the alternative is available, such as in the binary context, participants access the mental representation of the actual state of affairs (i.e., the figure being green) by looking at the alternative colour; instead, when there are many possible alternatives to describe the actual situation, such as in the multary context, participants do not access the mental representation of the actual state of affairs, but they focus instead on the mentioned colour, corresponding to the negated situation. It seems, therefore, that the shift towards the actual situation occurs only in the binary context, where participants keep in mind two possibilities (i.e., the negated and the actual situation) in order to make the inference between *The figure is not red* and *The figure is green*: in this case, negation is processed by representing the alternative affirmative. Conversely, in the multary context, participants do not represent the actual situation, but they rather maintain the negated argument: in this case, negation is represented symbolically, as a mental tag which applies to the information occurring under its scope (Beltràn et al. 2008; Clark & Chase 1972; Khemlani et al. 2012; Johnson-Laird 2001).

This hypothesis is supported by the temporal course of negation: while in the multary context participants fixated the mentioned colour 440ms after target word onset, the increase of fixations on the alternative colour started only 1340ms after the very same onset in the binary context. This suggests that it took time for participants to make the inference between the negated and the actual situation. Moreover, participants were slower in answering the final written questions in the binary context, probably because two different mental representations were maintained and must be evaluated in order to answer the question. If participants accessed the mental representation of the actual situation also in the multary context, the opposite pattern of reaction times would be expected: besides the figure corresponding to the negated situation, they would have to compare more possible alternative affirmative situations (three) with respect to the binary context (one) in order to evaluate the shape of all the figures involved in the discourse context. According to the authors, the shift of visual attention towards the alternative affirmative in the binary context would reflect the parser's preference to store an affirmative mental representation rather than the corresponding negative one, given that negation is harder to remember (Johnson-Laird 2001). However, keeping in mind two or more possible alternative affirmative situations might overload the working memory processing capacity, leading to computational errors (Johnson-Laird 2001). This would explain why, in the multary context, the parser prefers to maintain the mental representation of the negated situation: by doing so, however, participants focused on what is false (i.e., the red figure) in order to understand negation. This finding is quite at odds with all previous visual studies on language processing, which have widely demonstrated that listeners focus on the visual object that either corresponds to the referent or is to some extent related to it (Cooper 1974; Tanenhaus et al. 1995; Huettig & Altmann 2010; see §3.2.3.2). The authors accounted for this peculiarity by assuming that it reflects the communicative function of negation, that is, focusing on a false argument and rejecting it.

To conclude, the findings reported by Orenes et al. (2014) indicate that, in contrast to affirmation, negation promotes different patterns of fixations across verbal context: in multary contexts, the pattern resembled that for affirmatives, with increased fixations towards the mentioned colour, corresponding to the negated state of affairs; instead, in binary contexts, no increase of fixations on the mentioned colour was found, with participants rather looking at the alternative colour. According to the authors, these findings corroborate the hypothesis that there are two ways of processing negation, depending on the availability of the alternative: negative sentences are processed either by simulating the alternative affirmative or by applying a symbolic tag to the negated argument.

These results pose problems for the two-stage based processing proposed by Kaup et al. (2007, see §2.2.1.3), as they show that the representation of the actual state of affairs is not necessary to understand negation in multary contexts, where negation can be interpreted by maintaining its meaning in a symbolic format. Nevertheless, some relevant considerations on the result interpretation presented by Orenes et a. (2014) can be made.

For binary contexts, Orenes et al. (2014) reported only a short period of increased fixations on the mentioned colour (between 500ms and 800ms after target word onset), and increased fixations on the alternative colour from 1340ms after target word onset. This looking pattern behaviour has been taken as evidence that the parser represents the alternative affirmative situation (i.e., the green figure) when the verbal context makes such information available. However, in interpreting the results the authors did not account for the initial increase of fixations on the mentioned colour, which corresponds to the negated state of affairs described in the negative sentence. Interestingly, if we consider the temporal course of negative sentences in its entirety from the target word onset to the end of the time window, the participants' looking pattern behaviour in binary contexts can also be explained by assuming that negative sentences underwent a non-incremental interpretation process, as assumed by the Two-Step Simulation Hypothesis (§2.2.1.3). After the onset of the critical word (i.e., *red*) participants initially shifted their visual attention towards the picture representing the negated state of affairs (i.e., the red figure): since eye movements are closely time-locked to the processing of the unfolding linguistic input (Cooper 1974; Tanenhaus et al. 1995; Allopenna et al. 1998), initial fixations on the mentioned colour suggest that, at this point of the processing, participants were simulating the negated state of affairs, which corresponds to the first mental representation required in the comprehension process of negation. Nevertheless, this initial increase of fixations was quite short (only 300ms) because the visual context had already provided participants with the representation of the positive situation described in the negative sentence. As a consequence, the comprehension process was not significantly slowed down by the necessity to construct *ex novo* the representation of the negated state of affairs, which, instead, could be easily retrieved from the visual context. At 1340ms from the target word onset, participants focused on the picture representing the alternative affirmative (i.e., the green figure): at this later point of the processing, negation has been integrated into sentence meaning, and the mental simulation of the event has been modified accordingly to be consistent with the actual situation described in the negative sentence. All in all, the Two-Step Simulation Hypothesis can, thus, account not only for the delayed increase of fixations on the picture representing the actual situation (i.e., the green figure) compared to affirmative sentences (1340ms vs 500ms), but also for the initial increase of fixations on the mentioned colour (i.e., the red figure).

For multary contexts, Orenes et al. (2014) found that participants unexpectedly focused on what was false (i.e., the red figure) during negative sentence comprehension, with no increase of fixations on any of the possible alternative affirmatives. Nevertheless, this unusual looking pattern behaviour might have been influenced by specific experimental aspects, and it can be explained accordingly. On the one hand the authors have intentionally manipulated the verbal context, so to make a univocal alternative affirmative available only in the binary one, and on the other hand, this may have biased the process of reference resolution, which was not consistent across verbal conditions. Although participants were not asked to complete any specific task related to the comprehension of the target sentences (e.g., touching or moving visual objects, expressing metalinguistic judgements), the binary verbal context provided participants with an implicit task. The verbal context introduced the possibility that the mentioned figure could be either green or red. Subsequently, negation has been used to reject the possibility that the figure under discussion was coloured red. The use of negation in this discourse context was fully informative, and it allowed the listeners to infer that the green figure was the correct one to look at. Quite the opposite, the use of negative sentences in multary verbal contexts cannot be considered pragmatically felicitous: when more possible alternatives are available, a negative sentence such as *The figure is not red* is less informative than the corresponding affirmative *The figure is red*, because it excludes only one of the four possible referents in the visual context, and does not allow the listeners to infer any other relevant information about which is the figure under discussion.

For the aim of the present discussion, it is important to emphasize that the time-window analysed by Orenes et al. (2014), and shown in Figure 3.10, does not illustrate the participants' looking pattern behaviour until the end of the trail - that is, until the written question appears on the screen (3000ms), but only until 1900ms after the target word onset. Interestingly, on the one hand the temporal course of negative sentences in the multary context initially resembles that of affirmatives sentences, with increased fixations on the mentioned colour at around 500ms after target word onset, and on the other hand Figure 3.10 shows that these two patterns of fixations begin to differ later in the processing: while with affirmative sentences participants focused on the mentioned colour until the end of the time window, with negative sentences we can see a constant decrease of fixations on the mentioned colour, but, crucially, no corresponding increase of fixations on the alternative colour, which remains at chance rate (25% of fixation proportions[69]). Moreover, the temporal course of negative sentences suggests that, by the end of the time-window (1900ms after target word onset), fixations on the mentioned colour have reached chance level as well: it is therefore possible to assume that, after the initial increase of fixations on the mentioned colour, participants started to look at the four coloured figures equally frequently later in the processing. Therefore, participants' looking pattern behaviour would not necessarily indicate that the representation of the actual state of affairs is not needed to understand negation in multary contexts, as assumed by Orenes et al. (2014), but it might also be explained by taking into consideration the lack of informativeness of negative sentences uttered in such situational context.

[69] In a four-object visual set-up the visual scene is divided into four broad areas of interest, each containing one of the four objects: participants have a 25% chance of being already looking at one of the four pictures before the target word onset (*baseline effect*, see §3.2.2).

Unlike in the binary context, upon hearing the target negative sentence participants could not retrieve any relevant clue about what colour the figure under discussion was: while the binary verbal context provided participants with an implicit task, which made them focus on the figure representing the actual state of affairs, this task was not provided likewise by the multary verbal context. However, the question remains as to why in the multary context participants focused on the mentioned (but negated) colour instead of looking at the three possible alternatives.

A large number of experimental studies have demonstrated that the inhibition of the information under the scope of negation does not occur during the early moments of sentence comprehension, but rather between 750ms and 1500ms after the offset of the negative sentence (Kaup and Zwaan 2003; Hasson and Glucksberg 2006; Giora et al. 2007). In addition, there is substantial evidence indicating that the suppression of the argument of negation is functional to contextual consideration (Giora et al. 2004, 2007; Paradis & Willners 2006), as well as to the availability of a complementary concept (Mayo et al. 2014). Interestingly, the looking pattern behaviour for negative sentences in the multary context can be interpreted accordingly, as fixations on the mentioned colour started to increase at 500ms after target word onset, and a slight but steady decrease started at around 1100ms. General contextual aspects, such as the pragmatically infelicitous use of negation due to its lack of informativeness with respect to reference resolution might have resulted in a longer retention of the negated concept. This did not occur in the binary context, where the availability of an alternative had a facilitating effect on the suppression of the negated concept, as suggested by participants fixating the mentioned colour only for about 300ms (between 500ms and 800ms after target onset) before shifting their visual attention towards the alternative. Orenes et al. (2014) assume that in the multary context participants do not represent the actual situation, but they rather maintain the negated argument: this would indicate that when the alternative affirmative is not available, negation is represented symbolically as a mental tag, which applies to the information occurring under its scope.

Nevertheless, the retention of the negated argument might not necessarily imply a different way of processing negation: rather, it might simply indicate that negative sentences are processed slower when uttered in pragmatically infelicitous contexts. It has been widely demonstrated that the general processing difficulty generally associated with negative sentences can be attributed, at least in part, to their use either in isolation or in unsupportive pragmatic contexts (Wason 1959,1965; Dale & Duran 2011; Nieuwland & Kuperberg 2008; Staab et al. 2008; Ferguson et al. 2008 for pragmatic accounts §2.2.2.1, but see also Kaup et al. 2006 for the Two-Step Simulation Hypothesis, §2.2.1.3): due to their lack of informativeness in a multary verbal context, negative sentences were perceived by the comprehender as inappropriate, overloading the processing costs. Further corroborating evidence that pragmatic contextual information can modulate the processing of negation has been reported also in Orenes et al. (2015). Here, the authors accounted for the delay in target identification with negative sentences uttered in unsupportive pragmatic contexts as consequence of negation not being fully informative in such context of utterance: the comprehension process would have been slowed down by participants' need to adjust the contextual information.

Nevertheless, the temporal course of negative sentences in multary context can also be interpreted as evidence for a non-incremental processing of negation. The retention of the negated argument (i.e., the red figure) can indicate that, at this point of the processing, participants are simulating the first mental representation required in the comprehension process, namely that of the negated state of affairs. Similarly, we have seen that the Two-Step Simulation Hypothesis can also account for participants' looking pattern behaviour in binary context. In the binary context, participants could retrieve information from the linguistic context to make the inference between the negated and the actual situation: hence, they rapidly shifted their visual attention from the picture of the mentioned colour towards that of the affirmative one. Conversely, the lack of an attentional shift towards the possible alternatives in the multary context might be due to the unsupportive nature of the context of utterance, which has slowed down the integration of negation into sentence meaning: in this view, fixations on the mentioned colour would thus merely indicate a late inhibition of the mental simulation of the positive state of affairs. This hypothesis is supported by the stable decrease of fixations on the mentioned colour reported for multary negative contexts (Figure 3.10), which suggests that participants simply focused longer on the negated state of affairs compared to the binary context, but, eventually, started again to look at the four pictures equally frequently. The analysis of participants' looking pattern behaviour until the very end of the trial would have been useful to validate this assumption.

All in all, the time course of negative sentences across verbal contexts can also be explained by assuming that negative sentences always receive a non-incremental interpretation, regardless of the availability of the affirmative alternative, as assumed by the Two-Step Simulation Hypothesis (§2.2.1.3).

Throughout the chapter we have seen that language-mediated eye movements can be affected by different types of information (e.g., semantic, perceptual) provided in the visual scene, the unfolding linguistic input, and the linguistic context of utterance (§3.2.3). On the one hand the information provided by the negative sentence *The figure is not red* was not fully informative when uttered in the multary context, and on the other hand the colour red was certainly the most active information in participants' working memory: differently from the other colours, it was mentioned both in the sentence establishing the verbal context and in the target one. Significantly, several visual world studies have found that listeners' eye gaze is often directed towards pictures of objects which share some visual features (e.g., colour) with the target, but are semantically unrelated to it (Huettig & Altmann 2004, 2007: Dahan & Tanenhaus 2005; Yee et al. 2009; Huettig & Altmann 2011; Rommers et al. 2012). In particular, Huettig & Altmann (2011) have shown that language-mediated eye movements are strictly connected to surface perceptual properties of the visual objects (§3.2.3.1). In view of this, the participants' looking pattern behaviour in the multary negative context might have also been influenced by aspects of lexical activation, that occurs automatically during the unfolding of the linguistic input (Cooper 1974; Tanenhaus et al. 1995; Allopenna et al. 1998; Huettig & Altmann 2005). Hearing the target word *red* has led to the lexical activation not only of semantic but also perceptual properties of the corresponding concept: consequently, we can plausibly assume that the listeners focused their overt visual attention towards the object in the visual scene which shared the perceptual properties activated at lexical level by word semantics, and which are more active in the working memory after the target word onset. Moreover, note that the visual scene appeared 1000ms before the onset of the target sentence and 2500/2600ms before the onset of the target word, respectively.[70] Thus, it might be possible that the view of the objects depicted in the visual scene has primed the pre-activation of the corresponding lexical candidates before the onset of target word. This lexical pre-activation might have affected the integration of the linguistic and the visual input, by immediately directing the listeners' visual attention towards the object sharing surface perceptual properties with the mentioned target word (Huettig & McQueen 2007; Huettig et al. 2011). The initial pattern of fixations on the mentioned colour reported in the binary context can be explained likewise, as it might be affected by the online activation process of word semantics. Unlike in the multary context, the lexical activation effect was significantly reduced because participants could infer from the linguistic context which picture in the visual scene corresponded to the actual situation described in the negative sentence, and they were hence faster in shifting their visual attention towards it.

As already pointed out for Orenes et al. (2015), we cannot therefore completely exclude that language-mediated eye movements and attentional shifts during the temporal course of sentence processing do not correspond to actual stages of the comprehension process, but they are rather due to the lexical activation occurring automatically during the unfolding of the linguistic input (Cooper 1974; Tanenhaus et al. 1995; Allopenna et al. 1998; Huettig & Altmann 2005).

[70] Participants listened to the verbal context sentence lasting 3500ms. After that, the visual display appeared for 5500ms. After 1000ms of display preview, the target sentence started: the target word was delivered 1500ms (for affirmatives) and 1600ms (for negatives) after the target sentence onset. The time-window analysed was from 500ms before the onset of the critical word to 1900ms after.

3.3.3 Conclusive remarks on Orenes et al.'s studies

Orenes et al. (2015) provided compelling evidence that pragmatic information can modulate the processing of negation, which is facilitated when the negated event has been previously introduced in the situational context. Moreover, Orenes et al. (2014) have demonstrated that negative sentence comprehension is also affected by the verbal context of utterance, suggesting that negation can be processed either by representing the alternative situation or by applying a symbolic tag to the negated argument. However, it has become clear from the discussion that the interpretation of eye movement data is not always straightforward, as it may offer room for different theoretical interpretations. As a matter of fact, the results provided by both these studies can also be interpreted by assuming a non-incremental comprehension process, which is nonetheless facilitated when negative sentences are uttered in a supportive discourse context.

Moreover, as we will further discuss in the following section, aspects of lexical and perceptual activation must always be taken into consideration during the interpretation of eye movement data, as they might bias the real-time integration of linguistic and non-linguistic information from both the visual scene and the spoken input.

3.4 Visual World Paradigm: a new research tool for negation processing?

In light of what discussed so far, in this section we will outline the main advantages of studying the processing of negation using the visual world paradigm, as well as some experimental limitations which are intrinsically related to its visual nature and must, therefore, be taken into consideration when interpreting the eye movement data. These overall considerations will be starting point for the development of our study, which, as we will see in §3.5, aims at overcoming the intrinsic limitations of the visual paradigm by introducing for the first time some relevant modifications to the classical experimental design adopted by visual studies investigating negation processing.

As discussed in chapter 2, the processing of sentential negation has been extensively studied using sentence-picture verification tasks, in which participants are asked to determine the truthfulness of affirmative and corresponding negative sentences either against their pre-existing world knowledge or against a picture (Wason 1961; Gough 1966; Trabasso et al. 1971; Clark & Chase 1972; Carpenter & Just 1975; Kaup et al. 2006, 2007; Lüdtke et al. 2008; Giora et al. 2005; Hasson & Glucksberg 2006; Vender & Delfitto 2010). In such an experimental configuration, sentence comprehension is assessed by measuring participants' response latencies and accuracy in expressing metalinguistic judgments about what they have observed and heard during the test trial. Nevertheless, response choices and reaction times are behavioural measures of language comprehension which provide information on the final linguistic comprehension of the target sentence, but they do not give any insights on how visual and linguistic stimuli interact *in real time* to reach this final understanding. While accuracy can in all respects be considered an offline measure of sentence comprehension, as it is based on the listener's final interpretation of the sentence itself, the reaction times collected during task execution cannot be properly considered as online behavioural data, as they are generally measured from the offset of the target sentence until the formulation of the metalinguistic judgment. In addition, visual stimuli are employed only in function of determining the truth-value of the sentence: as a consequence, the result interpretation does not account for how this visual source of information is integrated with the unfolding linguistic input, and how this integration can affect the online comprehension process.

The visual world paradigm overcomes these methodological limitations by providing extremely precise information on the time course of sentence processing. In particular, eye movement data can give important insights on how visual and linguistic stimuli interact during the processing of both affirmative and negative sentences, and to what extent the different pictures presented in the visual scene are exploited by the parser during the online comprehension process. From the literature, it is well known that the listener immediately integrates spoken linguistic information with that provided by the visual context: eye movements are closely time-locked to the processing of the unfolding linguistic input, as they reflect the interactions between linguistic and visual representations occurring at conceptual level (Cooper 1974; Tanenhaus et al. 1995; Allopenna et al. 1998; Dahan & Tanenhaus 2005; Altmann & Kamide 2009; see §3.2). It follows that, likewise for affirmative sentences, when people listen to negative assertions in a visual world set-up they are expected to look more frequently at the most active information in their working memory. For instance, in Orenes et al. (2015) we have seen that after hearing a linguistic context consistent with the actual situation described in the negative sentence (i.e., the dad being rich), the participants' gaze was already biased towards the picture of a rich man before the onset of the target word: the reverse pattern was found when the linguistic context was consistent with the negated situation (i.e., the dad being poor), with participants fixating the picture of a poor man from the earliest moments after the presentation of the visual scene. This suggests that participants' eye overt attention was captured by the most active information in their working memory, and it reflected the activation of the corresponding mental representation. This is particularly useful in order to understand whether the positive representation of the argument of negation (i.e., the negated state of affairs) is activated during the online comprehension process. Consider again the results reported in Orenes et al. (2015) for the consistent context (§3.3 – Figure 3.8), which was consistent with respect to the negative meaning conveyed by the target sentence (i.e., the dad being rich): although participants' gaze was initially biased towards the target picture (i.e., the rich dad), the eye movement analysis clearly showed that participants momentarily shifted their visual attention towards the picture of a poor man, corresponding to the negated state of affairs. Such an early attentional shift might indicate the activation of the corresponding mental representations, which, according to the Two-Step Simulation Hypothesis, constitutes the first step of the comprehension process of negative sentences.[71]

In addition, the analysis of the listener's looking pattern behaviour can indicate exactly when negation is integrated into sentence meaning during the online comprehension process. This is made possible by analysing the time course of negative and corresponding affirmative sentences against the same visual scenario (Orenes et al. 2014; Tian et al. 2010). Given that the only difference between the two polarity conditions consists in the introduction of negation at the linguistic level, it follows that any difference in participants' looking pattern behaviour can be attributed to the integration of negation into the semantic meaning of the sentence. Consider for instance the results reported by Orenes et al. (2014) for affirmative and negative sentences in the binary context (Figure 3.10). Participants' looking pattern behaviour for negative sentences initially resembled that for affirmatives, with an increase of fixations on the mentioned picture (i.e., the red figure), which does not match the negative meaning of the sentence but rather corresponds to the representation of the negated state of affairs. Only at 1340ms from the target word onset, participants eventually focused on the picture matching the actual situation (i.e., the green figure). This clearly suggests that negation was integrated only at a later point into sentence meaning, namely when participants' looking pattern behaviour started to differ from that in the corresponding affirmative sentence.

Conversely, studies on negation processing conducted within the sentence-picture verification paradigm evaluate the moment of integration of negation into sentence meaning on the basis of the different reaction times reported for the task execution. For instance, Kaup et al. (2006) introduced a variable delay between the offset of the target sentence *The door is not open* and the presentation of the visual stimulus (either an open or a closed door). Results showed that participants were faster in recognizing the picture of an open door (i.e., the negated situation) when the delay was of 750ms; instead, after 1500ms of delay, they were faster in recognizing the picture of a closed door (i.e., the actual situation). This pattern of findings has been taken as evidence that negation is integrated later in the processing, between 750ms and 1500ms after the offset of the negative sentence (§2.2.1.3). However, offline measures of sentence comprehension cannot provide precise information on how the visual stimuli provided affect the integration of negation into sentence meaning, and when this integration occurs.

[71] The interested reader can refer to §3.3 for a detailed discussion of the results.

Differently from classical experimental paradigms, in which participants are asked to express metalinguistic judgments about the sentence's truth-value, in visual world studies participants are simply asked to listen to the sentences while they are free to look wherever they want on the screen. The simplicity of the visual world set-up makes the task execution extremely effortless: participants are not asked to do anything different from what they do in their everyday life when they automatically integrate information from written and spoken sources of information (e.g., while listening to the news on TV). This definitely represents another advantage of the visual world paradigm in several respects. First of all, the data collected are not compromised by external factors such as mental fatigue. During the performance of complex task, such as evaluating the truthfulness of a sentence against a visual scenario, working memory resources are widely exploited: as underlined by Deutsch et al. (2006), this working memory taxation has a negative impact on the computation, and it might result in greater processing difficulties for negative sentences, especially when uttered in unsupportive contexts (§2.2.1.3). This makes the visual world paradigm perfectly suitable to assess the comprehension of negative sentences by groups of listeners who might have difficulty in performing too complex tasks due to their limited working memory resources, namely children (Nation et al. 2010; Mani & Huettig 2014; Tribushinina & Mak 2016)[72] and impaired populations such as aphasics (Walsh et al. 2007; Yee et al. 2008), and dyslexics (Rayner 1998; De Luca et al. 1999; Hutzler & Wimmer 2004; Desroches et al. 2006; Stoodley & Stein 2006; Huettig & Brouwer 2015; Benfatto et al. 2016). Lastly, the need to accomplish metalinguistic judgments might affect the listeners' comprehension strategy, as they might focus on specific aspects of the sentence and the visual scene which, instead, might not be taken into much consideration during the sentence comprehension process occurring within a normal communicative context. Conversely, a visual world set-up allows participants to manage the pace of their comprehension, as the interpretation process does not require the evaluation of the sentence's truth value, hence resembling the way language is used during everyday communication.

Another advantage of the visual world set-up is that all objects, including possible competitors, are simultaneously displayed in the visual scene (Orenes et al. 2014, 2015; Huettig & McQueen 2007; Dahan & Tanenhaus 2005; Huettig & Altmann 2011; Allopenna et al. 1998; Reinisch et al. 2010; Altmann & Kamide 1999, among others). Consider for instance Orenes et al. (2015), where the visual display for the target sentence *Her dad was not poor* consisted in two pictures: one of a rich man, matching the actual state of affairs, and one of a poor man, matching instead the negated situation. When presented with this visual scenario, participants were free

[72] Age range of children tested: 5;0-8;0 years old (Nation et al. 2010); 3;0-3;5 years old (Tribushinina & Mak 2016); 8;0-8;11 years old (Mani & Huettig 2014).

to turn their visual attention towards whatever picture was needed for the dynamic update of the mental representation of the event described by the negative sentence. In turn, this has allowed researchers to understand not only what type of visual information was retrieved during sentence processing, but also the exact moment during the unfolding of the linguistic input in which such information was accessed and processed. Quite the opposite, in classical sentence-picture verification tasks participants are usually presented with only one picture, matching either the actual or the negated state of affairs (Kaup et al. 2006, 2007; Lüdtke et al. 2008, among others). Besides often resulting in instances of pragmatic infelicity, which has been argued to burden the processing of negative sentences (Wason 1965; Nieuwland & Kuperberg 2008; Dale & Duran 2011; see §2.2.2.1), this visual configuration does not provide any insights on how the different pictures are exploited to reach the final comprehension of the negative meaning of the sentence.

To conclude, using the visual world paradigm to study negation processing can provide significant evidence as concerns those aspects of the comprehension process which are of central interest for the theoretical debate outlined in chapter 2 and for the aim of the present study: namely, the role of the argument of negation in the interpretation process, and how quickly negation is processed and integrated into sentence meaning during online comprehension.

The main advantage of using the visual world paradigm to study negation is that, unlike psycholinguistic studies conducted using classical methodologies[73], it provides exhaustive information on the time course of sentence comprehension. The analysis of participants' looking pattern behaviour allows researchers to determine how the visual sources of information are exploited by the parser during the comprehension process, and at which point negation is integrated into the semantic meaning of the sentence. These online measures of sentence comprehension cannot be provided, or at least not directly, by classical experimental methodologies, such as the sentence picture verification task, which rely on accuracy and reaction times to investigate the processing of negative

[73] In chapter 2 we have seen that other experimental methodologies have been employed to study negation processing, such as EEG-ERP recording (e.g., Fischler et al. 1983; Lüdtke et al. 2008) and neuro-imaging techniques (Tettamanti et al. 2008; Tomasino et al. 2010; Liuzza et al. 2011; Alemanno et al. 2012; Bartoli et al. 2013; Foroni and Semin 2013; Papeo et al. 2012). Neurolinguistic studies were not included in the present discussion since, so far, they have provided evidence concerning only limited aspects of negation processing, and cannot, therefore, be compared with experimental findings from traditional verification paradigms (see §2.2.2.2 for a detailed discussion). Conversely, the investigation of ERP correlates during and after the reading of affirmative and negative sentences is surely more sensitive to subtle online aspects of the processing with respect to response choices and reaction times. Nonetheless, the EEG-ERP studies described in §2.2.1.3 and §2.2.2.1 were always conducted within a sentence-picture verification set-up, thus presenting the same limitations here described for psycholinguistic studies conducted using the classical sentence-picture methodology.

sentences. While sentence-picture verification tasks focus on the final linguistic comprehension of the negative sentences, visual world studies provide extremely precise information on how visual and linguistic sources of information interact during the real-time comprehension process in order to reach this final understanding.

On the one hand the visual world paradigm is extremely suitable for studying the unfolding comprehension process of sentential negation, and on the other hand it is not free from methodological limitations, which make the interpretation of eye movement results hardly straightforward.

Throughout the chapter we have seen that language-mediated eye movements are significantly affected by the lexical activation of the words encountered as the linguistic input unfolds: this activation occurs automatically, and leads to the retrieval of not only semantic but also perceptual properties of the mentioned linguistic items (Cooper 1974; Tanenhaus et al. 1995; Allopenna et al. 1998; Huettig & Altmann 2005). A large number of visual world studies have demonstrated that the lexical activation of a term encountered in the linguistic input can influence participants' overt visual attention towards semantically or perceptually related objects in the visual scene (Huettig & Altmann 2005; Huettig & Altmann 2004, 2007; Dahan & Tanenhaus 2005; Yee et al. 2009; Huettig & Altmann 2011; Rommers et al. 2012). Instances of lexical access are intrinsically related to the visual nature of the paradigm, and represent its main limitation with respect to the interpretation of eye movement data: hearing a word automatically elicits the mental activation of its semantic and perceptual features, and the listener's attention is drawn towards those objects in the visual scene which share some of these features with the mentioned word.

As a consequence, the interpretation of patterns of fixations and attentional shifts occurring during the online sentence processing must necessarily take into account the possibility that these language-mediated eye movements do not correspond to actual stages of sentence comprehension, but they rather reflect the lexical activation process occurring during the unfolding of the linguistic input. Consider, for instance, the results reported in Orenes et al. (2014) for negative sentences presented in the binary verbal context (Figure 3.10). In §3.3, we have argued that the initial pattern of fixations on the mentioned colour (i.e., the red figure) can be interpreted as evidence for a non-incremental processing of negative sentences (§2.2.1.3), indicating that, at this early point in the processing, the listeners are simulating the first of the two mental representations required for the comprehension of the negative sentence *The figure is not red*, namely that of the negated situation (i.e., the figure being red). Nevertheless, the very same increase of fixations on the mentioned colour can also be explained by assuming that participants' looking pattern behaviour was simply affected by the lexical activation of the concept *red*, which has elicited a shift in their visual attention towards the object in the visual scene sharing the perceptual properties activated at lexical level by hearing the word *red* in the speech stream.

Another related methodological issue concerns the pre-activation of word candidates, and the subsequent retrieval of lexical information, primed by the view of the objects depicted in the visual scene. A series of findings reported by Huettig & McQueen (2007) and Huettig et al. (2011) have provided compelling evidence that a long preview of the objects depicted in the visual scene before the onset of the spoken input (e.g., more than 1s) allows listeners to rapidly access the corresponding lexical items. This lexical pre-activation can significantly influence the way in which the visual information is integrated during the sentence comprehension process, as participants might be faster in directing their gaze towards those visual objects sharing semantic, perceptual, and also phonological features with the mentioned word. In Orenes et al. (2014) the visual scenario depicting the four coloured figures appeared 2500/2600ms before the target word onset, and it is therefore likely to assume that this visual preview has primed the pre-activation of the corresponding lexical candidates. As a consequence, upon hearing the target word *red*, participants might have immediately directed their gaze towards the red figure because the retrieval of the lexical properties of the mentioned term would have been facilitated by the fact that these properties had already been activated through the preview of the visual scene. Evidence for a lexical pre-activation primed by the visual scene comes from Orenes et al. (2015), where the analysis of participants' looking pattern behaviour showed how their gaze was biased towards the picture consistent with the linguistic context provided *before* the onset of the target sentence (Figure 3.8): when the linguistic context was congruent with the representation of a rich man (e.g., *Her dad had enough savings*), participants already focused on the target picture of a rich man; instead, when the linguistic context was congruent with the representation of a poor man (e.g., *Her dad had little savings*), their visual attention was drawn to the picture of a poor man (see §3.3 for further details). Significantly, in this experiment the visual scene was previewed for two seconds before the onset of the target sentence: the different patterns of fixations across linguistic contexts clearly indicate that this preview has allowed participants to immediately retrieve the lexical information from the depicted items (i.e., a poor and a rich man), and to integrate it with that provided by the linguistic context, being thus able to rapidly identify the picture corresponding with the described situation.

As discussed above, one of the advantages of the visual world set-up is that all the relevant pictures are simultaneously displayed in the visual scene: this allows researchers to understand how the different pictures, representing for instance the negated and the actual situation described in the negative sentence, are exploited during the online comprehension process. However, the result interpretation is far from being straightforward, as it is difficult to discriminate whether attentional shifts towards the visual objects indicate the real-time activation of the corresponding mental representations occurring during negation processing, or rather the lexical activation of the mentioned terms, which occurs automatically during the unfolding of the linguistic input and can also be primed from the preview of the visual scenario. In addition, as pointed out by Huettig et al. (2011), the presence of different pictures on the visual display might encourage the listeners to make inferences that would not normally be drawn in the normal use of language processing. Dale and Duran (2011) have observed that negation is not always used in pragmatically felicitous situations during everyday communication (§2.2.2.1): therefore, it might be the case that, in a normal situation in which the negated state of affairs is not at the listeners' disposal, they would not spend time in evaluating it. In a visual world set-up, instead, the listeners might tend to look at the corresponding picture only because they have it at their disposal, and this might bias the sentence comprehension process. It follows that, especially for comprehension studies, it is often difficult to determine the contribution of visual and linguistic processing to a pattern of findings, which, as we have seen in §3.3, can frequently fall within different theoretical frameworks.

This difficulty in result interpretation is closely related to another key feature of the visual world paradigm, namely the absence of a metalinguistic feedback on sentence comprehension. On the one hand, this makes task execution extremely effortless, but on the other hand it does not provide the researchers with any hints on whether participants have reached the final understanding of the negative sentence, which is instead assessed in more classical experimental paradigms such as the sentence picture-verification task. One might argue that it is unlikely that participants do not understand the experimental sentences, whose interpretation is often unchallenging - especially for adults. However, since participants are not asked to identify the picture corresponding to the sentence negative meaning, we cannot exclude that fixations on a given picture are merely the result of the lexical activation process described above, with participants focusing on the picture corresponding to the most active information in their working memory. This is exactly what we assumed in §3.3 for patterns of fixations on the mentioned (negated) colour in multary verbal contexts in Orenes et al. (2014). Instead, the presence of an explicit reference resolution task such as, for instance, *Find the picture that is not red*, would have forced listeners to interpret the sentence negative meaning in order to find the corresponding picture in the visual scene, providing further insights as to whether fixations on a given picture (e.g., the red figure) were related to actual stages of the comprehension process.

Nevertheless, the presence of a task of reference resolution cannot completely resolve the problem of lexical interference, which, as we have seen, occurs systematically as the linguistic input is heard. In addition, the implementation of a reference resolution task within a visual-world set up raises another methodological issue, which is always intrinsically related to the visual nature of the paradigm itself.

Consider for instance a visual scene as the one in Figure 3.11, with two pictures displayed on the screen: one of Jasmine cuddling a tiger and one of Jasmine feeding a bird, respectively. When participants are presented with the affirmative sentence *Jasmine is cuddling a tiger* and they are asked to find the picture matching with the described situation, they are immediately able to identify the matching picture in the visual context. As a matter of fact, the affirmative sentence already provides participants with relevant linguistic information on the described situation, which allows them to immediately activate the corresponding mental representation and identify the referent in the visual scene by looking at the picture of Jasmine cuddling a tiger. In turn, they perceptually inhibit the picture of Jasmine feeding the bird, which is not relevant for the reference resolution process, by not paying attention to it. When participants are presented with affirmative sentences, the cognitive processes of activation and inhibition are carried out on different pictures during online reference resolution. Instead, these processes compete with each other on the very same picture when participants are presented with negative sentences and the same visual scenario. Significantly, the corresponding negative assertion *Jasmine is not cuddling a tiger* does not provide participants with any precise information on what picture displayed in the visual scene is the referent of the situation described by the negative sentence. Therefore, in order to understand which is the correct picture to look at to accomplish the task, participants must first activate and identify in the visual scene the picture corresponding to the positive situation described by the negative sentence (i.e., Jasmine cuddling a tiger), which then must be inhibited so to reflect the sentence negative meaning: by inference from the visual context, participants will eventually shift their visual attention towards the picture of Jasmine feeding a bird, which constitutes the visual referent of the negative sentence within that specific visual set-up.

Figure 3.11. Example of visual world set-up for the sentences *Jasmine is/is not cuddling a tiger*

Together with the lexical activation issues outline above, this competition occurring on the picture representing the argument of negation constitutes the most problematic aspect of investigating negation processing using the visual world paradigm. As a matter of fact, possible looks at the picture matching the negated situation (e.g., Jasmine cuddling a tiger) might be the consequence of both the lexical activation process and the exploration of the visual scene occurring during reference resolution: given that the more active the information is (both linguistically and perceptually), the more difficult it is to divert attention from it, looks on the picture of the negated argument do not necessarily indicate an actual stage of the ongoing negative sentence comprehension process, but they may also merely reflect the fact that the listeners' visual attention is drawn towards the picture corresponding to the most active information in their working memory.

All in all, these methodological limitations are intrinsically related to the visual nature of the paradigm: they cannot be eliminated – lexical activation occurs automatically during the unfolding of the linguistic input, nor balanced – the cognitive processes of activation and inhibition necessarily occur on the same picture during the reference resolution process for negative sentences. However, they can be controlled by manipulating the visual prominence of the picture representing the argument of negation in the visual scenario. In the next section we will see how the methodological limitations here discussed can be overcome by means of this visual manipulation, allowing us to provide a clear interpretation of the eye movement results with respect to the theoretical research questions on negation processing outlined in chapter 2, which are of central interest for the aim of the present study.

3.5 Rationale and research questions

Although the processing of sentential negation has been a matter of a considerable amount of research, psycholinguistic findings have so far provided conflicting evidence as concerns core aspects of the processing. In particular, in chapter 2 we have seen that it is still under debate what is the role of the argument of negation in the interpretation process, as well as how quickly negation is computed and integrated into the semantic meaning of the sentence.

On the one hand, non-incremental accounts of negation processing, such as the Two-Step Simulation Hypothesis (Kaup et al. 2007), have provided consistent evidence that negation is not immediately integrated into sentence meaning, as the interpretation of a negative statement would necessarily first undergo the evaluation of its positive counterpart. In this view, the additional computational step involved in the comprehension process determines the higher processing costs which traditionally characterize negative sentences compared to the corresponding affirmative ones: the processing of negative sentences is considered to be inherently more complex than that of affirmatives, as it always requires the construction of one more mental simulation (i.e., the negated state of affairs). From this theoretical assumption it follows that supportive pragmatic contexts can have a facilitating effect on the computation: during the early stages of the processing, the comprehenders can benefit from being presented with a picture depicting the negated state of affairs, as they can retrieve the mental simulation under construction directly from the discourse situation instead of creating it *ex novo*. Nevertheless, even when a felicitous pragmatic context is provided, negative sentences are more demanding than the corresponding affirmatives due to the nature of the mental simulations involved in the comprehension process (§2.2.1.3). Interestingly, a large number of experimental studies have provided evidence in favour of this non-incremental view of negation processing: both sentence-picture verification tasks (Kaup et al. 2005; 2006; 2007; Hasson & Glucksberg 2006) and EEG-ERP studies (Fischler et al. 1983; Lüdtke et al. 2008) have reported higher processing difficulties for negative sentences with respect to corresponding affirmatives and, among negative sentences, a facilitation effect when a pragmatically felicitous context is provided.

On the other hand, incremental accounts of negation processing have reported contrasting evidence, showing that, exactly as it happens for non-negative words, the semantic contribution of negation is immediately integrated into the sentence meaning. The processing of negative sentences would hence resemble that of the corresponding affirmatives, with no need to necessarily represent the positive counterpart to access the semantic negative meaning. In this view, the higher processing costs reported for negative sentences are a consequence of a pragmatically infelicitous context of utterance, which requires the parser to adjust the lacking contextual information and consequently slows down the comprehension process. If presented in a supportive discourse context, the processing of negative sentences would hence not require extra processing time nor effort in comparison with that of the corresponding affirmatives (§2.2.2.1). Compelling evidence in favour of an incremental view of negation processing has been reported not only by more classical experimental paradigms (Wason 1965; Glenberg & Robertson 1999; Dale & Duran 2011; Giora 2006; Giora et al. 2007; Mayo et al. 2004), but also by ERP-EEG (Nieuwland & Kuperberg 2008; Staab et al. 2008) and neuro-imaging studies (Tettamanti et al. 2008; Tomasino et al. 2010; Liuzza et al. 2011; Alemanno et al. 2012; Bartoli et al. 2013; Foroni and Semin 2013; Papeo et al. 2012): interestingly, the latter have shown that while the processing of affirmative action-related sentences induces the activation of motor areas, the presence of linguistic negation immediately inhibits the activation of the very same brain networks.

Quite intuitively, psycholinguistic researchers are far from an agreement on these main aspects of the processing, as the experimental evidence provided by classical experimental paradigms investigating language comprehension and neurolinguistic techniques appears quite heterogenous and, in some respects, also contradictory. As discussed in the previous sections (§3.3, §3.4), investigating the processing of negation using the visual world paradigm can give important insights with respect to these aspects of the comprehension process. As a matter of fact, the analysis of the listeners' looking pattern behaviour can provide extremely precise information on the real-time course of sentence interpretation, allowing researchers to determine how the visual sources of information (in particular the picture representing the negated situation), are exploited by the parser during the comprehension process, and at which point of the computation negation is integrated into the semantic meaning of the sentence. These online measures of sentence comprehension are not provided by classical experimental methodologies such as sentence-picture verification task, which assess the final linguistic comprehension of the negative sentence but are unable to explain how vision and language interact in real time to reach this understanding. However, throughout the chapter we have seen that the visual world set-up is not free from methodological limitations, which can bias the listeners' looking pattern behaviour during the real-time comprehension process. Having the picture representing the negated situation in the visual scene allows researchers to understand whether it is actively exploited by the listeners during the negative sentence comprehension process: however, it cannot be excluded that fixations on a given picture during the unfolding of the linguistic input are biased by lexical activation or by the visual process of reference resolution. These visual biases can be overcome by manipulating the prominence of the picture representing the argument of negation in the visual scene. Significantly, this manipulation allows to investigate the role of the argument of negation (henceforth, *mentioned argument*[74]) during the online processing of negative sentences by controlling at the same time issues related to lexical activation and visual reference resolution.

Consider again the referential context presented in Figure 3.11: in the previous section we have seen that, when presented with the negative sentence *Jasmine is not cuddling a tiger*, during the visual reference resolution process the listeners must first activate and identify the picture corresponding to the negated situation (i.e., Jasmine cuddling a tiger), which then is inhibited so to reflect the sentence negative meaning and find the correct referent in the visual scene. Incremental accounts of negation processing assume that the activation of the representation of the mentioned argument is not required to access the negative meaning of the sentence: as a consequence, the need to inhibit this representation during the reference resolution process would slow down the interpretation process. On the contrary, non-incremental accounts, and more in particular the Two-Step Simulation Hypothesis (Kaup et al. 2007), assume that the activation of the very same representation is always required in the comprehension process of negative

[74] We defined it as *mentioned argument* because i) it represents the argument of negation, intended as the semantic information occurring under its scope; ii) it is in all respects mentioned, as it is explicitly expressed in the sentence.

sentences. Having the picture of the negated argument at disposal in the visual scene would hence facilitate the processing: in fact, sentence computation is usually slowed down by the need to retrieve this negated information, as occurs when negative sentences are presented in pragmatically infelicitous contexts. Manipulating the visual prominence of the picture depicting the mentioned argument can, therefore, shed a light on whether it is the activation or the inhibition of the argument of negation which burdens the processing cost of negative sentences compared to that of the corresponding affirmatives, and, consequently, it can provide compelling evidence on when negation is integrated during the sentence comprehension process.

The visual manipulation consists in varying the number of pictures representing the negated argument from one to three, creating three different experimental conditions (Figure 3.12): the more the pictures depicting the mentioned argument, the more the pictures that must be activated and then inhibited in order to interpret the sentence negative meaning and identify the visual referent in that specific discourse context.

Significantly, we have seen that incremental and non-incremental accounts of negation processing make opposite predictions on what may hinder the processing of the negative sentence *Jasmine is not cuddling a tiger* compared to the corresponding affirmative. Therefore, if it is the activation and the retrieval of the negated information which slows down the processing of negative sentences, as assumed by the Two-Step Simulation Hypothesis, having more pictures of the mentioned argument displayed in the visual scene should have a facilitating effect on the interpretation process: as a matter of fact, the representation of the negated situation, which constitutes the first step in the processing, is much easier to retrieve from the visual scene when it is perceptually more prominent. Instead, if the activation of the mentioned argument is not required for the interpretation process of negative sentences, as assumed by incremental accounts, having more pictures representing the negated situation displayed in the visual scene would hinder the comprehension process: in fact, these pictures, which have been activated only as consequence of the lexical interference and the visual reference resolution process, are made more difficult to inhibit by their visual prominence.

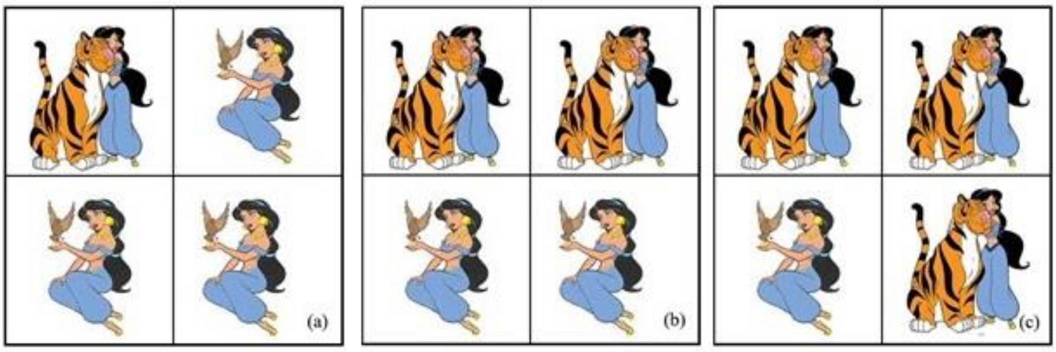

Figure 3.12. Example of visual scenarios including one (a), two (b), and three (c) pictures of the mentioned argument.

Longer fixations on the picture representing the mentioned argument with negative sentences than with affirmatives can be considered a precise measure of processing cost, as they indicate a delay in target identification. Consider for instance the sentence *The figure is red* and the corresponding negative assertion *The figure is not red* presented against the same visual scenario showing a red and a green figure: while in the affirmative condition the red figure corresponds to the target picture, in the negative condition it corresponds to the picture that must be inhibited (i.e., the negated state of affairs). When the listeners' looking pattern behaviour in the negative condition deviates from that in the affirmative one, shifting from the red figure (i.e., the target for affirmatives) to the green figure (i.e., the target for negatives), it means that the information occurring under the scope of negation has been suppressed, and negation has been integrated into sentence meaning. Significantly, the comparison of the listeners' looking pattern behaviour between affirmative and corresponding negative sentences across visual scenes containing a variable number of pictures of the mentioned argument can provide clear evidence on whether having more pictures representing the argument of negation on the screen makes participants faster or slower in target identification for negative sentences.

To conclude, the manipulation of the visual prominence of the mentioned argument allows us to answer the following research questions, which are of central interest for the theoretical debate on negation processing outlined in chapter 2:

i) what is the role of the argument of negation in the interpretation process?

Incremental models of negation processing assume that the mental representation of the argument of negation is not a mandatory step in the interpretation process of negative sentences since the semantics of negation immediately affects sentence comprehension (§2.2.2). Instead, non-incremental models of negation processing, such as the Two-Step Simulation Hypothesis (Kaup et al. 2007), consider the mental representation of the argument of negation to play a central role in the comprehension process, as it is always required for the computation of the sentence negative meaning (§2.2.1.3).

The analysis of the listener's looking pattern behaviour can shed a light on the exact role of the argument of negation in the interpretation process: possible fixations towards the picture representing the mentioned argument can provide important evidence on whether the visual representation of the mentioned argument is actively exploited by the parser during real-time comprehension (§3.3). Significantly, the manipulation of the visual prominence of the mentioned argument allows us to interpret eye movement data by ruling out possible visual biases due to reference resolution and to effects of lexical activation.

ii) how quickly is negation integrated into sentence meaning?

Incremental models of negation processing assume that the processing of negative sentences does not require extra time nor effort compared to that of affirmatives, since negation is immediately integrated into sentence meaning (§2.2.2). Evidence for an early integration of negation comes in particular from neuro-imaging studies, showing an immediate inhibition of brain motor areas during the comprehension of negative sentences (§2.2.2.2). Conversely, the Two-Step Simulation Hypothesis considers the interpretation process of negative sentences to be inherently more costly than that of affirmatives, due to the additional computational step required (i.e., the activation and the subsequent inhibition of the representation of the negated state of affairs): the integration of negation would hence occur only later on during the comprehension process (§2.2.1.3).

Eye movement data can provide precise information concerning how quickly negation is integrated into sentence meaning by comparing the listener's looking pattern behaviour during the real-time interpretation of affirmative and corresponding negative sentences. The deviation of the eye gaze pattern in the negative condition from that in the affirmative one indicates the moment in which negation affects sentence interpretation. Once again, the manipulation of the visual prominence of the mentioned argument can provide significant evidence on what overloads the processing costs of negative sentences (i.e., the activation or the inhibition of the negated information) by comparing the moment in which negation is integrated across visual scenes with a different visual prominence of the mentioned argument.

As we will see in detail in chapter 4, the implementation of an *identification task with eye recording* which includes this manipulation of the visual scenario will assess the final sentence comprehension and provide, at the same time, unbiased eye movement data on the time course of sentence interpretation. This new experimental protocol aims at combining the strength of both the classical sentence-picture verification task and the visual world paradigm so to overcome their intrinsic limitations and exhaustively study how linguistic and visual processes jointly determine the online understanding of negative sentences.

4 The online processing of sentential negation

This chapter is dedicated to our main experiment on the processing of sentential negation by Italian-speaking adults, and is organized as follows. In the first section (§4.1), we will describe in detail the design of our *identification task with eye recording* and the visual manipulation that we decided to introduce. Then, in §4.2, we will focus on the description of the materials and the procedure employed for the task, and we will outline our predictions with respect to the research questions discussed in §3.5. In §4.3, we will present in detail the results from the behavioural and the eye-movement analysis conducted. The next section (§4.4) will be focused on the theoretical implications of the present findings. Finally, in section §4.5, we will conclude by summarizing how our experimental study has contributed to the broad theoretical debate on the processing of sentential negation discussed in §2.

4.1 The current study

The goal of the present study is to investigate the timing and the mode of negation integration into sentence meaning, as well as the role of the argument of negation in the interpretation process. In order to do so, we realized an *identification task with eye recording* to compare the time course of sentence comprehension during the processing of affirmative and negative sentences. Participants heard affirmative and corresponding negative sentences while looking at a visual scene containing four sets of pictures, and their eye movements were recorded. This classical visual world set-up (Altmann & Kamide 1999; Huettig & Altmann 2005; Huettig & McQueen 2007) was implemented via an identification task, in which participants were asked to identify the visual referent of the verbal description, and press a button upon identification. This methodology combined the advantages of offline experimental paradigms (e.g., Truth-Value Judgment Task, Sentence-Picture Verification Task), which focus on more cognitive aspects of sentence processing, and the visual world paradigm, which provides extremely precise information on how linguistic and visual processes interact during online sentence comprehension. Therefore, this experimental protocol provided us with a useful tool to investigate the online processing of negative sentences compared to their affirmative counterparts, but at the same time included a metalinguistic feedback to assess sentence comprehension.

In this experiment, participants heard affirmative (1) and negative (2) sentences while presented with a visual scenario containing four sets of pictures, and they were asked to identify the visual referent of the verbal description: during the task, their eye movements were recorded.

(1) Aladdin is closing the door and Jasmine is cuddling a tiger
(2) Aladdin is not closing the door and Jasmine is cuddling a tiger

The visual scene included at least one picture representing the described state of affairs and one visual competitor. Crucially, for negative sentences, the visual competitor corresponded to the representation of the argument of negation (i.e., the mentioned argument). Unlike in previous studies on negation processing[75], we manipulated the visual prominence of the mentioned argument by presenting such experimental sentences with three possible types of visual scenario, in which the number of pictures of the mentioned argument (e.g., Aladdin closing the door) parametrically varied from one to three (Figure 4.1).

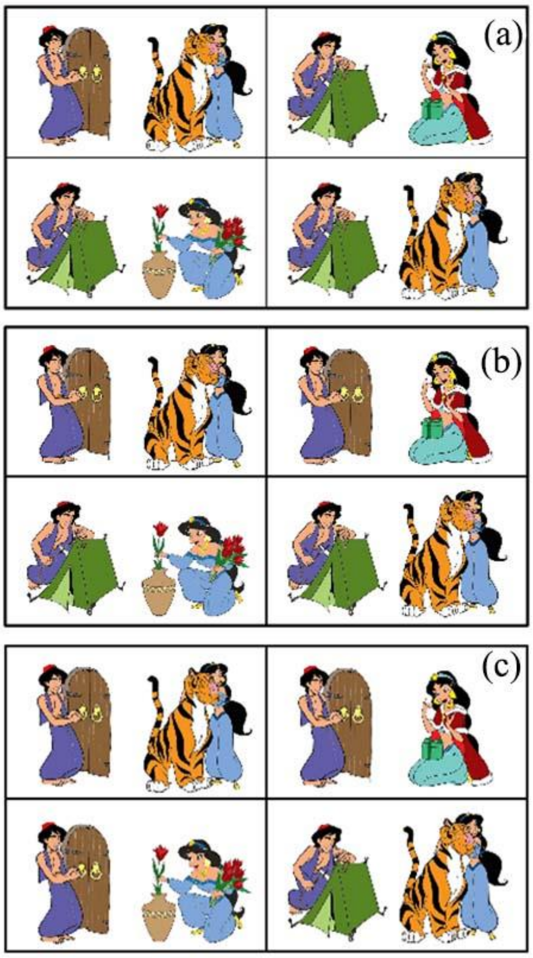

Figure 4.1. Example of visual scenario with one (a), two (b), and three (c) quadrants including the visual representation of the mentioned argument for the sentences *Aladdin is closing the door* (AFF) and *Aladdin is not closing the door* (NEG) - (i.e. Aladdin closing the door). The visual scenario in (a) includes 1 target for AFF and 3 potential targets for

[75] The interested reader can refer to §3.4 for a detailed discussion of the main experimental features of previous works on negation processing conducted within different experimental paradigms.

NEG. The visual scenario in (b) includes 2 potential targets for both AFF and NEG. The visual scenario in (c) includes 3 potential targets for AFF and 1 target for NEG.

Based on this manipulation, the number of potential targets and competitors varied across experimental conditions. In addition, within the same visual scene, the picture of the mentioned argument could be either the target or the competitor depending on sentence polarity. Consider, for instance, the three visual scenarios in Figure 4.1 for sentences (1) and (2). The picture of the mentioned argument (i.e., Aladdin closing the door) corresponds to the visual referent of the affirmative sentence (1): hence, the more the pictures of the mentioned argument, the more the potential targets of the verbal description. In contrast, the visual referent of the negative sentence (2) is the picture of Aladdin pitching a tent: in the negative condition, the pictures of the mentioned argument correspond to the pictures to avoid, as they represent the negated rather than the actual state of affairs. Therefore, as the number of pictures of the mentioned argument increases, the number of potential targets increases in the affirmative condition, but it decreases in the negative one.

The manipulation of the visual prominence of the mentioned argument created an initial ambiguity in the reference resolution task, as the visual scene could include more potential referents of the verbal description. Consider, for instance, the experimental scenario in Figure 4.1b. After hearing the main clause *Aladdin is closing the door*, participants could immediately identify as potential targets the two pictures of Aladdin closing the door in the upper quadrants. Conversely, after hearing the corresponding negative statement *Aladdin is not closing the door*, participants recognized as potential targets the two pictures of Aladdin pitching the tent in the lower quadrants. Crucially, we exploited this visual ambiguity to investigate how participants made use of the visual information, in particular the picture of the mentioned argument, during the real-time interpretation of affirmative and corresponding negative sentences. This ambiguity was then solved linguistically with the introduction of the coordinate clause *Jasmine is cuddling a tiger*, which allowed participants to identify a univocal visual referent of the verbal description: namely, the upper left picture for the affirmative sentence, and lower right picture for the negative one. The disambiguating clause was introduced for reasons of task felicity, as it provided a visual referent for the target clause across all the experimental conditions. In doing so, we managed to overcome one of the major experimental limitations reported for Orenes et al. (2014): as argued in §3.3.2, in this study the lack of a univocal referent in the *multary* negative context might have biased participants' looking pattern behaviour during the look-and-listen task. However, note that for the aim of the present study, we were mainly interested on the real time processing of the main clause, which was the one manipulated in terms of polarity (e.g., *Aladdin is/is not opening the door*). From now on, we will refer to this main clause as target sentence.

As we will see more in detail in the following sections, three different types of stimuli were included in the present study: cartoon characters, coloured and black and white geometric shapes. Each of these visual stimuli was paired with a different type of declarative sentence, which could denote performed actions and events (i.e., cartoon characters, see §4.2.2.1), perceptual properties (i.e., coloured geometric shapes, see §4.2.2.3) or existential properties of the described entities (i.e., black and white geometric shapes, see §4.2.2.2). This allowed us to investigate whether the processing of sentential negation might vary across different linguistic and perceptual dimensions, and how the complexity of the visual and the linguistic input might affect the construction of the negative meaning.

4.2 Methods

4.2.1 Participants

A total of 62 Italian adults aged 19;1- 32;6 (M = 22,4; *SD* = 3,03) participated in the study. All participants were volunteers and were recruited at the University of Verona (in the North-East of Italy) via an online subject pool. All of them were native Italian-speakers, 11 were male. They had normal or corrected to normal vision by means of soft contact lenses or glasses. None of the participants had reported history of speech, hearing or language disorders.

The study was approved by the local Ethics Committee of the University of Verona, and was conducted in accordance with the standards specified in the 2013 Declaration of Helsinki.

4.2.2 Materials

This experiment had a 2x3 within-subjects factorial design. The two independent variables were sentence polarity (affirmative/negative) and number of pictures of the mentioned argument (MA), which parametrically varied from one to three. The combination between these two variables generated the following six experimental conditions:

Condition	**Sentence polarity**	**MA pictures**
1	Affirmative sentence	1 picture
2	Affirmative sentence	2 pictures
3	Affirmative sentence	3 pictures
4	Negative sentence	1 picture
5	Negative sentence	2 pictures
6	Negative sentence	3 pictures

Each of these experimental conditions was further manipulated so to balance the exact location of the target and the competitor in the visual scene: within the same experimental item, two possible sentence-picture combinations were included for each of the six conditions. To exemplify, the following visual scene for the condition (5) could be paired either with the sentence *Aladdin is not closing the door and Jasmine is cuddling a tiger* or with the sentence *Aladdin is not pitching a tent and Jasmine is cuddling a tiger*. In the first combination, the target picture was in the lower right quadrant, while in the latter it was in the upper left one.

Figure 4.2. Example of visual scenario for the experimental condition (5). The target picture can be either bottom-right or upper-left depending on the paired negative sentence.

Each experimental item generated, therefore, twelve possible combinations for a total of 1440. Twelve lists of stimuli were created using the Latin-square design: each item only appeared once in each list, in one of the twelve conditions. For each list, half of the sentences were negatives. The full set of sentences created for one of the twelve lists is reported as an example in Appendix A.

The task included a total of 120 experimental trials, distributed among three different types of stimuli: 48 items for cartoon characters, 36 items for black and white geometric shapes, and 36 items for coloured geometric shapes, respectively. Each type of stimulus was used as filler items for the other two types of item. As described in §4.1, each experimental item was composed of a sentence paired with a visual scene consisting of four sets of pictures. Experimental sentences were recorded by a young female speaker of Italian, who was instructed to read all the sentences with a neutral intonation, resulting in typical declarative Italian sentences. All the sentences were digitally edited through the *Audacity* software.

We will now describe in detail the materials employed for the three types of stimuli, which were created following the experimental design outlined above.

4.2.2.1 Cartoon characters

All the pictures consisted of easily recognizable cartoon couples. In order to facilitate character recognition, they were introduced to the participants before the beginning of the test, namely during the familiarization session (§4.2.3). A total of eight fixed cartoon couples were chosen: Aladdin and Jasmine; Donald Duck and Minnie Mouse; Daisy and Mickey Mouse; Bart and Lisa Simpson; Snow White and the Little Mermaid: Tom and Jerry; Bugs Bunny and Tweety; Winnie the Pooh and Piglet. Each couple appeared in six items. In all the pictures, the two characters were performing two different easily recognizable actions involving common objects (e.g., closing the door, driving the car). The position of the two characters in the quadrant was fixed across items (e.g., Aladdin on the left and Jasmine on the right). The number of times in which the target character appeared in the right or the left side of the picture was balanced: for each couple, in half of the items the character performing the target action was the one on the left (e.g., Aladdin), while in the other half it was the one on the right (e.g., Jasmine). The two characters never performed the same action, not even on different objects (e.g., eating a different fruit).

Experimental sentences were Italian declarative sentences with a singular agent subject, a transitive verb in simple present tense[76], and an inanimate entity as direct object complement. A coordinate or subordinate clause was introduced for task felicity (§4.1): the agent subject could be either the same of the main clause (5) or the other character of the cartoon couple (4). The manipulation of sentence polarity affected only the main clause, as exemplified below:

(3) Aladdin is closing the door and Jasmine is cuddling a tiger
(4) Aladdin is *not* closing the door and Jasmine is cuddling a tiger
(5) Aladdin is *not* closing the door but (he) is pitching a tent[77]

Each sentence, in both affirmative (3) and negative (4-5) polarity was paired with three types of visual context, in which the number of pictures of the mentioned argument parametrically varied from one to three (see Fig. 4.1 in section 4.1).

Note that, within the same visual scenario, the picture of the mentioned argument (i.e., Aladdin closing the door) could be either the target or the competitor

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[76] Italian present indicative tense has a progressive function and is commonly used for present-time actions in progress. Hence, the present progressive is used for the English adaptation.

[77] English translation of the original Italian sentences:

(3) Aladdin chiude la porta e Jasmine coccola una tigre
Aladdin close.PRS.3SG the door and Jasmine cuddle.PRS.3SG a tiger
'Aladdin closes the door and Jasmine cuddles a tiger'

(4) Aladdin non chiude la porta e Jasmine coccola una tigre
Aladdin not.NEG close.PRS.3SG the door and Jasmine cuddle.PRS.3SG a tiger
'Aladdin does not close the door and Jasmine cuddles a tiger'

(5) Aladdin non chiude la porta ma monta una tenda
Aladdin not.NEG close.PRS.3SG the door but pitch.PRS.3SG a tent
'Aladdin does not close the door but pitches a tent'

depending on sentence polarity. In the positive condition (3), the pictures of the mentioned argument corresponded to the potential targets: in the negative one (4;5), instead, they represented the pictures to avoid, as they corresponded to the visual representation of the negated state of affairs. It follows that, as the number of pictures of the mentioned argument increased, the number of potential targets increased in the affirmative condition (3) whereas it decreased in the negative one (4;5).

For each list, half of the cartoon items were paired with negative sentences. Of the negatives, half of the sentences included a subordinate clause (5), and half a coordinate clause (4). All sentences lasted between 6000ms and 7000ms, of which: 2000ms for task description (i.e., *Look at the quadrant in which…*) and between 4000ms and 5000ms for the proper test sentence. Picture quality and properties had been equalized (dpi 100, 600x600 pixels) using *Photoshop* software.

4.2.2.2 Coloured geometric shapes

The pictures displayed in the visual scene consisted of three coloured geometric shapes each: a square, a triangle, and a circle. In order to avoid confusion in shape recognition, the position of the three geometric shapes in the quadrant was fixed across items, as shown in Figure 4.3. Moreover, each geometric shape had two specific colours: the square could be either black or grey, the triangle either yellow or green, and the circle either red or blue. It was never the case that, for instance, a triangle was coloured in red.

The visual prominence of the mentioned argument has been manipulated within the same visual scene. We introduced a different ratio between the colours employed for each geometric shape[78] (e.g., squares 3:1 – circles 2:2 – triangles 1:3, see Figure 4.3): then, we paired the visual scene with affirmative and negative sentences having the different geometric shapes as subject of the verbal description. The very same visual scene generated all the experimental conditions in both sentence polarities: an example of the stimuli associated with each experimental condition can be found in Figure 4.3.

Experimental sentences were Italian declarative sentences with copulative predicates in simple present tense of the form of "*The* (geometric shape) *is/is not* (colour)". A coordinate clause was introduced for task felicity (§4.1) only in those experimental conditions in which the target referent was not univocal. Similarly to cartoon items, the manipulation of sentence polarity affected only the main clause.

[78] The ratio between the coloured shapes changed across items (e.g., squares 2:2 . circles 1:3; triangles 3:1)

Polarity	Sentence
AFF	**1 MA** *Il triangolo è verde* The triangle be.PRS.3SG green "The triangle is green"
	2 MA *Il cerchio è rosso e il triangolo è verde* The circle be.PRS.3SG red and the triangle be.PRS.3SG green "The circle is red, and the triangle is green"
	3 MA *Il quadrato è grigio e il cerchio è blu* The square be.PRS.3SG grey and the circle be.PRS.3SG blue "The square is grey, and the circle is blue"
NEG	**1 MA** *Il triangolo non è verde e il quadrato è nero* The triangle not.NEG be.PRS.3SG green and the square be.PRS.3SG black "The triangle is not green, and the square is black"
	2 MA *Il cerchio non è rosso e il quadrato è nero* The circle not.NEG be.PRS.3SG red and the square be.PRS.3SG black "The circle is not red, and the square is black"
	3 MA *Il quadrato non è grigio e il cerchio è blu* The square not.NEG be.PRS.3SG grey and the circle be.PRS.3SG blue "The square is not grey, and the circle is blue"

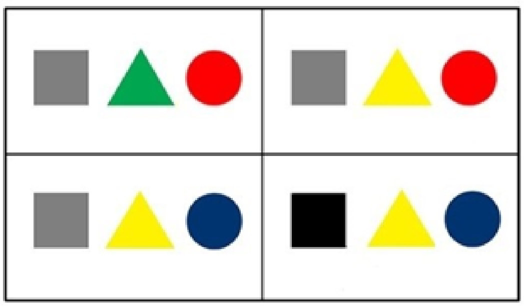

Figure 4.3. Example of experimental conditions for a coloured geometric shape item.

The picture of the mentioned argument (e.g., the green triangle in the sentence *the triangle is/is not green*) could be either the target or the competitor depending on sentence polarity. The ratio between the number of pictures of the mentioned argument and the number of potential targets is directly proportional in the affirmative condition, but inversely proportional in the negative one.

For each list, half of the coloured geometric shape items were paired with negative sentences. Test sentences lasted either between 4000 and 5000ms (simple sentence) or between 6000ms and 7000ms (sentence with coordinate clause) – the first 2000ms were used for task description. Pictures quality and properties had been equalized (dpi 144, 288x288 pixels) using *Photoshop* software.

4.2.2.3 Black and white geometric shapes

The pictures displayed in the visual scene consisted of two black and white geometric shapes each. In order to avoid confusion in shape recognition, a total of five easily recognizable shapes were chosen: a square, a circle, a triangle, a pentagon, and a star. The position of the geometric shapes was fixed within the visual scene (e.g., the circle on the right and the square on the left – see Figure 4.4), but changed across items.

The visual prominence of the mentioned argument has been manipulated within the same visual scene. We presented the geometric shapes in different quantities[79] (e.g., three circles, two pentagons, one star), and we paired this visual scene with affirmative and negative sentences having the different geometric shapes as subject of the verbal description. The very same visual scene generated all the experimental conditions in both sentence polarities: an example of the stimuli associated with each experimental condition can be found in Figure 4.4.

Experimental sentences were Italian declarative sentences with existential statements in simple present tense of the form of "*There is/is not a* (geometric shape)". A coordinate or subordinate clause was introduced for task felicity (§4.1) only in those experimental conditions in which the target referent was not univocal. Similarly to the other types of stimuli, the manipulation of sentence polarity affected only the main clause.

[79] The ratio between the number of shapes changed across items (e.g., three squares, two triangles, one circle)

Polarity	Sentence
AFF	**1 MA** *C'è una stella* There_be.PRS.3.SG a star "There is a star"
	2 MA *C'è un pentagono e una stella* There_be.PRS.3.SG a pentagon and a star "There is a pentagon, and a star"
	3 MA *C'è un cerchio e un pentagono* There_be.PRS.3.SG a circle and a pentagon "There is a circle, and a pentagon"
NEG	**1 MA** *Non c'è una stella ma un pentagono* Not.NEG there_be.PRS.3.SG a star but a pentagon "There is not a star, but a pentagon"
	2 MA *Non c'è un pentagono ma un quadrato* Not.NEG there_be.PRS.3.SG a pentagon but a square "There is not a pentagon, but a square"
	3 MA *Non c'è un cerchio* Not.NEG there_be.PRS.3.SG a circle "There is not a circle"

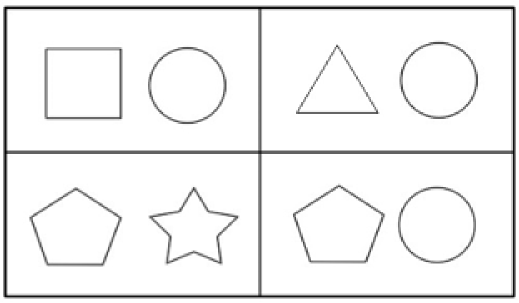

Figure 4.4. Example of experimental conditions for a black and white geometric shape item.

The picture of the mentioned argument (e.g., the star in the sentence *there is/is not a star*) could be either the target or the competitor depending on sentence polarity.

The ratio between the number of pictures of the mentioned argument and the number of potential targets is directly proportional in the affirmative condition, but inversely proportional in the negative one.

For each list, half of the black and white shape items were paired with negative sentences. Test sentences lasted either between 3000ms and 4000ms (simple sentence) or between 5000ms and 6000ms (sentence with coordinate/subordinate clause) – the first 2000ms were used for task description. Pictures quality and properties had been equalized (dpi 144, 288x288 pixels) using *Photoshop* software.

4.2.3 Apparatus and procedure

Apparatus and Eye Tracking Recording. Participants' eye movement were recorded at a rate of 1000 Hz using an SR Research EyeLink 1000 Plus head-mounted eye tracker connected to a 24" colour BenQ monitor for visual stimulus presentation. The experimental procedures were implemented in Python. Calibration and validation procedures were carried out using a nine-point display at the beginning of the experiment, and were repeated several times per experimental session. Participants were tested individually in a soundproof room at the Laboratory of Text, Language and Cognition (LaTeC) of the University of Verona.

Procedure. Before the beginning of the test, participants were informed that they would listen to a series of sentences while some pictures would be displayed in the four quadrants of the screen. They were instructed to listen carefully to the sentences, as their task was to find the picture corresponding to the verbal description. To choose the correct picture, they simply had to keep looking at the corresponding quadrant while pressing the space bar for confirmation. Participants were also informed that the pictures would stay on the screen until they decided to press the space bar: although they had no time limit for making their decision, they were told that it was important to accomplish the task as quickly and accurately as possible. No response-contingent feedback was provided during the test.

The experimental session was preceded by a practice and a familiarization block. The practice block consisted of six trials similar to those used as experimental items: two trials with a different sentence polarity were presented for each type of visual stimuli (i.e., cartoons, coloured, and black and white shapes). None of the cartoon characters presented in the practice block were also used in the proper experiment. Similarly, neither the combination of geometric shapes within the same quadrant nor the combination of shapes and colours were the same adopted for the experimental items. The practice trials were useful for the participants to familiarize with the task, and to make sure that they had correctly understood the instructions. At the end of the practice block the experimenter asked participants whether anything about the task or the overall experiment was unclear, and answered to possible clarifying questions.

Practice trials were followed by a familiarization block, during which participants were introduced to the cartoon character couples included in the experiment. Eight cartoon couples were displayed on the screen while participants heard a sentence such as *The one on the left is Donald Duck, and the one on the right is Minnie Mouse.*[80] Participants were only asked to listen carefully to the characters' presentations. The familiarization session was useful for participants to recall the names of the different cartoon characters: the aim was to avoid possible biases on the pattern of fixations due to the fact that participants might not recognize who was carrying out the action described in the sentence.

An example of one experimental trial is shown below in Figure 4.5. The trial started with a one-second presentation of a central fixation cross for drift correction. Then, a scene with four pictures (as described in §4.2.2) appeared on the screen. Participants had 2000ms to preview the images before the audio stimuli started. After the onset of the target sentence, the visual scene remained displayed on the screen until participants pressed the space bar. In order to move to the next trial, participants had first to listen to the entire sentence: if the space bar was pressed during the presentation of the audio stimulus, this did not affect the task execution. The trial concluded with the appearance of the written instruction *Press space bar to continue*: this allowed participants to manage the pace of the task execution, so to avoid possible mental fatigue due to the rapid succession of many trials.

[80] English translation of the original Italian sentence:
Quello a sinistra è Paperino e quella a destra è Minnie
That at left be.COP.PRS.3SG Donald Duck and that at right be.COP.PRS.3SG Minnie Mouse
'The one on the left is Donald Duck, and the one on the right is Minnie Mouse'

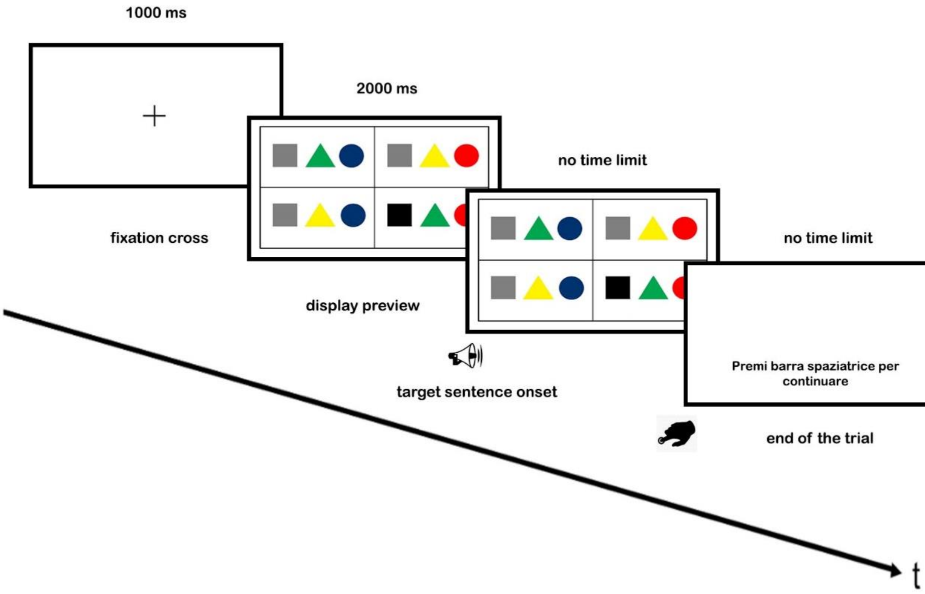

Figure 4.5. Experimental procedure

The testing session lasted approximately one hour. The 120 experimental items were presented in 2 blocks of 60 items each: at the end of the first block, participants had the possibility to take a break for as long as they preferred. They were asked to stay seated as still as possible throughout the duration of each experimental session: after the break, the procedures of calibration and validation were repeated. At the end of the experimental session, participants were informed on the goal of the research.

4.2.4 Predictions

The manipulation of the visual prominence of the mentioned argument allowed us to investigate whether it was the activation or the inhibition of the negated information which hindered the processing costs of a negative sentence such as *Aladdin is not closing the door* compared to the corresponding affirmative. If the processing of negative sentences were slowed down by the need to retrieve and activate the mental representation of the negated information, this evidence would be in compliance with what assumed by the Two-Step Simulation Hypothesis (Kaup et al. 2007 see §2.2.1.3), which considers the activation of the negated information as a mandatory step in the comprehension process of negative sentences. Instead, if it were the inhibition of the negated information which slowed down the processing of negative sentences compared to the corresponding affirmatives, this evidence would strongly support an incremental processing strategy of negation (§2.2.2), which maintains that the argument of negation must not necessarily be activated (and subsequently inhibited) in order to interpret negative sentences (among others, Nieuwland & Kuperberg 2008, Dale & Duran 2011).

The processing costs for negative sentences can be measured in terms of fixations on the pictures of the mentioned argument, as they indicate a delay in target identification (§3.5). After the verb onset, the listeners were able to identify the potential visual referents of the verbal description[81]: when the listeners' looking pattern behaviour deviated from that in the affirmative condition, it meant that negation had been integrated into sentence meaning. We compared participants' looking pattern behaviour between affirmative and negative sentences across experimental conditions: this comparison provided compelling evidence on how the visual prominence of the mentioned argument affected target identification[82]. Consider again, for ease of reference, the following visual scene:

[81] For both affirmative (a) and negative (b) sentences the Disambiguation Point (DisP) which allows participants to identify the potential visual referents of the verbal description is the verb onset. Note that for the negative sentence the DisP occurs immediately after the onset of negation.
(a) Aladdin is [DisP] closing the door / Aladdin [DisP] chiude la porta
(b) Aladdin is not [DisP] closing the door / Aladdin non [DisP] chiude la porta
[82] We consider as fixations towards the target the fixations towards all the possible visual referents of the main clause, which is affected by both the linguistic (sentence polarity) and visual manipulation (number of MA pictures).

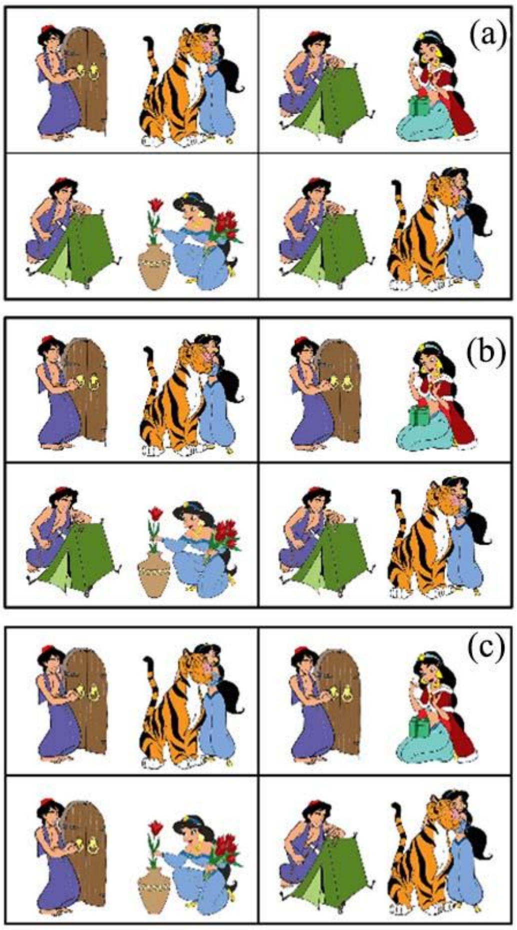

Figure 4.6. Example of visual scenario with one (a), two (b), and three (c) quadrants including pictures of the mentioned argument.

The pictures of the mentioned argument corresponded to potential targets in the affirmative condition. Quite intuitively, we can assume that, when presented with the affirmative sentence *Aladdin is closing the door*, participants would have been faster in target identification when more pictures of the mentioned argument (i.e., more potential targets) were displayed in the visual scene. Participants' looking pattern behaviour with affirmative sentences was our baseline.

It should be noted that the pictures of the mentioned argument corresponded instead to the visual competitors in the negative condition. If it was the inhibition of the negated information which slowed down the processing of the negative sentence, we were expecting an *increased penalty* for target identification compared to the affirmative baseline as the number of pictures of the mentioned argument increased. In terms of looking pattern behaviour, we were expecting participants to be faster in shifting their gaze from the picture of Aladdin closing the door (i.e., negated situation) to that of Aladdin pitching a tent (i.e., the target) as the number of potential targets increased (a). This pattern of results would strongly support an incremental view of negation processing (see §2.2.2): if the activation of the mentioned argument is not required for the interpretation process of negative sentences, a greater visual prominence of the pictures representing the negated situation would make their inhibition more difficult.

Instead, if it was the activation of the negated information which slowed down the processing of the negative sentence, we were expecting the opposite pattern, with a *reduced penalty* for target identification compared to the affirmative baseline as the number of pictures of the mentioned argument increased. In terms of looking pattern behaviour, we were expecting participants to be faster in shifting their gaze from the picture of Aladdin closing the door (i.e., negated situation) to that of Aladdin pitching a tent (i.e., the target) as the number of visual competitors increased (c). Crucially, this pattern of results would strongly support the Two-Step Simulation Hypothesis (Kaup et al. 2007, see §2.2.1.3): as a matter of fact, having more pictures representing the negated situation would have a facilitating effect on the interpretation process, as this would make easier the retrieval and the activation of the first mental representation required.

Note that, despite the facilitating effect of the visual prominence of the mentioned argument, the Two-Step Simulation Hypothesis (Kaup et al. 2007) also predicted that the processing costs for negative sentences could not be completely eliminated: the processing of negative sentences is inherently more demanding than that of the corresponding affirmatives, as it involves more complex and partially different cognitive representations (§2.2.1.3). In terms of looking pattern behaviour, the Two-Step Simulation Hypothesis (Kaup et al. 2007) predicted a delay in target identification for negative sentences compared to the affirmative baseline – even if minimal – across all the experimental conditions.

Instead, incremental models predicted that the processing costs for negative sentences could be completely eliminated: the processing of negative sentences is not intrinsically different from that of affirmatives when an adequate pragmatic context is provided[83] (among others, Nieuwland and Kuperberg 2008, Dale & Duran 2011 see §2.2.2). In terms of looking pattern behaviour, incremental models predicted no delay in target identification for negative sentences compared to the affirmative baseline at least in the easiest condition.

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[83] For the current experiment we adopted a pragmatically controlled design: i) the actions and the subjects mentioned in the test sentences (in both polarities) were always displayed in the visual scene ii) the use of negation in the discourse context was always fully informative: despite a temporary and intended visual ambiguity, the test sentences always allowed the listeners to infer a univocal target picture across all the experimental conditions.

4.3 Results

4.3.1. Behavioural data

Behavioural measures concern the acceptance rate of the target picture at the end of each trial. The aim of the behavioural analyses was to assess participants' final sentence comprehension, and to make sure that participants had been actively involved in task execution.

First, we found that participants' final choices were not affected by sentence polarity: on average, they correctly identified the visual referent of the verbal description 67% of the time when presented with affirmative sentences, and 68% of the time when presented with the negative ones. Furthermore, we investigated whether the accuracy rate might be affected by the type of item (i.e., cartoon characters, coloured and black and white geometric shapes). Table 4.1 shows that the accuracy in target identification was consistent across types of items and sentence polarity. Participants were able to identify the target picture about 68% of the time with black and white geometric shapes, regardless of sentence polarity. For cartoon characters, the accuracy rate is about 69% with affirmative sentences and 66% with negative ones. Coloured geometric shapes display a slightly higher accuracy rate with participants finding the target picture 69% of the time with affirmative sentences and 71% of the time with negative ones. The fact that the average accuracy was not very high (> 65%) can be explained by possible experimental artefacts: first, participants might be committed to the experiment and tried to answer faster at the expense of accuracy, though there was no time limit for selecting a picture; second, participants might be looking elsewhere on the screen instead of looking at the target picture while pressing the space bar.[84]

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[84] In order to be sure that the results were not biased by the performance of subjects with a low accuracy, we also performed all the analyses by including only those subjects with an accuracy rate above the calculated median value (> 66%), for a total of 45 out of 62 subjects. The results of both behavioural and eye movement analyses replicated those obtained by including all 62 participants, both in terms of statistical significance and looking pattern behaviour, suggesting that the low accuracy rate did not affect the online sentence comprehension performance. To be noted, in our eye movement analyses, we were mainly interested on the real-time processing of the main clause, which was the one manipulated in terms of polarity: instead, the accuracy rate concerned the listener's final interpretation of the entire experimental sentence (i.e., upon hearing the disambiguating subordinate/coordinate clause). The consistency between the results of the analyses performed on the two different groups of subjects can therefore be explained accordingly.

Polarity	**Item Type**	**Accuracy**
Affirmative	Black and white geom. shapes	.68
	Cartoon characters	.69
	Coloured geom. shapes	.69
Negative	Black and white geom. shapes	.68
	Cartoon characters	.66
	Coloured geom. shapes	.71

Table 4.1. Average accuracy in target identification for affirmative and negative sentences across item types

At first glance, it seems that the recognition task was not affected by the type of visual and linguistic stimuli provided, nor by the sentence polarity. In order to verify this observation, we conducted a mixed-effects logistic regression model with *accuracy* (correct vs. incorrect) as dependent variable, and *polarity* (AFF vs. NEG) and *item type* (cartoon characters, black and white, and coloured geometric shapes) as independent variables using the packages lme4 and lmer Test in R (Bates et al. 2015, Kuznetsova et al. 2017). Participants and items were added as crossed random effects (random intercepts). Random slopes for participants and items were included if this improved the fit of the model (as estimated by comparing the logLikelihoods of the models using the anova-function in R). Non-significant interactions were removed from the model. The statistical analysis confirmed that the accuracy in target identification was not affected by the main effects of *polarity* (x2 = 0.02, df = 1, p = .900) and *item type* (x2 = 0.36, df = 2, p = .835). However, the model revealed a significant *polarity* × *item type* interaction (x2 = 7.14, df = 2, p < .01), suggesting that the response accuracy among item types was differently modulated by the polarity of the sentence. To disentangle the nature of this interaction, data were split according to *polarity* and the effect of *item type* was investigated for these two subsets. For affirmative sentences, results showed that there was no significant effect of *item type* on the accuracy rate (x2 = 0.41, df = 2, p = .815), as indicated by similar values across the three item type conditions: .69, .68, and .69 for cartoon characters, black and white, and coloured geometric shapes, respectively. A significant effect of *item type* was instead reported for negative sentences (x2 = 9.94, df = 2, p < .001). Post-hoc comparisons with Tukey correction of p-values (emmeans()-function in R) revealed that, when presented with negative sentences, participants' accuracy rate in target identification was significantly higher (*ß* = 0.34, SE = 0.12, z = 3.15, p = < .001) with coloured geometric shapes (71%) than with cartoon characters (66%).

Taken together, these results indicate that participants understood the task correctly, and that participants' final choices were not affected by sentence polarity per se. Overall, the task execution was neither affected by the type of linguistic stimuli provided. However, it is worth noting that, among negative sentences, target identification was less accurate with cartoon characters than with coloured geometric shapes, hinting at some sensitivity of negation processing related to the propositional and perceptual features of the presented stimuli. While these behavioural data provide an important feedback on participants' final sentence comprehension, they do not offer any relevant insights on how visual and linguistic sources of information interact during the real-time comprehension process in order to reach this final understanding. In the following sections, we will examine the results coming from the online data with the aim of disentangling possible effects of polarity and visual prominence of the mentioned argument on the real-time sentence processing.

4.3.2 Eye movement data

The computation of the eye-movement data generated by the EyeLink system was performed through an open source Python-based visual world experiment analysis. The statistical analyses were conducted using the LmerTest Package (Kuznetsova et al. 2017) for the R platform. The time period analysed was from the onset of the critical word (Disambiguation Point - DisP) to 2000ms after its onset, and was divided into 50-ms time slots. Crucially, the DisP allowed participants to identify the potential visual referents of the verbal description for both affirmative and negative sentences, and it corresponded to the onset of the mentioned argument (6-8).

(6) Aladdin is/is not [DisP] closing…
(7) The triangle is/ is not [DisP] green…
(8) There is/is not [DisP] a pentagon…

The two-second time period was chosen on the basis of previous studies, so to guarantee that there would be enough time for participants to comprehend negation (Kaup et al. 2006, Lüdtke et al. 2008, see §2.2.1). Moreover, it allowed us to determine exactly how the visual prominence of the mentioned argument affected the real-time target identification across experimental conditions. Within this time period, we identified as major area of interest the one-second time-window from the offset of the critical word (650ms) to the onset of the coordinate/subordinate clause (1650ms). The length and the onset of this broad time-window have been matched across items and conditions.

Three eye-movement analyses were conducted. In the descriptive analyses on the target and on the mentioned argument, we visually explored the time course of sentence interpretation by subdividing the time period of interest in 50ms time-slots. In the statistical analysis on the target, we sought statistical confirmation of possible patterns of fixations emerged in the exploratory descriptive analysis on the target in our major area of interest (650ms-1650ms from the DisP onset).

In the descriptive analysis on the target, the graphs show the value of the target preference for the selected time period computed in 50ms time-slots. The target preference corresponds to the time spent fixating the target (i.e., the visual referent of the verbal description) as a proportion of the total time spent in fixating both the target and the competitor. Note that, for negative sentences, the visual competitor corresponded to the mentioned argument. If the target preference equals 1, it means that every participants in every trial was looking at the target during the whole time-slot. If it equals 0, it means that they were looking at the competitor . Instead, values between 1 and 0 indicate that some participants were looking at the target whereas others were looking at the distractor. Significantly, we considered as target fixations those towards all the possible visual referents of the target sentence: if, for instance, the affirmative sentence *The triangle is green* appeared with a visual scenario including two pictures of a green triangle, we considered as fixations towards the target the fixations towards both these pictures

In the descriptive analysis conducted on the mentioned argument, the graphs show the value of the Mentioned Argument (MA) preference for the selected time period computed in 50ms time-slots. The MA preference is calculated as a proportion of a total time spent in fixating both the mentioned argument and the competitor. As in the previous analysis, we considered as MA fixations those towards all the pictures of the mentioned argument depicted in the visual scenario: if, for instance, the negative sentence *The triangle is not green* was presented with a visual scenario including two pictures of a green triangle, we considered as MA fixations those towards both these pictures. Note that the picture of the mentioned argument represented the target picture in the case of affirmative sentences: instead, it represented the competitor in the case of the negative ones, as it corresponded to the visual representation of the negated state of affairs. As a consequence, looks towards the mentioned argument in the negative condition denote a delay in target identification: the deviation of the eye gaze pattern from that in the affirmative one indicates the moment in which negation affects sentence interpretation. Again, we had a different baseline for MA preference across experimental conditions including a different number of MA pictures: .25 in the condition with one mentioned argument; .50 in the condition with two mentioned arguments; .75 in the condition with three mentioned arguments.

In the statistical analysis, the target preference, computed over the time-window identified as our area of interest (650ms-1650ms), has been investigated across experimental conditions including one, two, and three potential targets. The main goal of this analysis was to provide statistical confirmation of possible effects of the visual prominence of the mentioned argument on target identification in the negative condition compared to the affirmative baseline.

The three types of stimuli employed in the task (i.e., cartoon characters, coloured, and black and white geometric shapes) corresponded to three different experimental conditions. These will be analysed separately in the following sections. For each type of stimuli, we will first present the exploratory results from the descriptive analysis on the target by comparing participants' looking pattern behaviour during the time course of AFF and NEG sentence interpretation in each experimental condition (i.e., one, two, and three potential targets). Then, we will illustrate the target preference analysis computed over the broad time-window (650ms-1650ms) across experimental conditions including a different number of potential targets. To conclude, we will visually explore the patterns of fixations towards the mentioned argument to understand whether participants exploited the visual representation of the negated information during the online negative sentence comprehension.

4.3.2.1 Cartoon characters

Descriptive analysis on the target

One potential target. The graph in Figure 4.7 depicts the proportion of looks to the target after the Disambiguation Point (9), computed in 50ms time-slots, for the conditions including one potential target. The affirmative condition (AFF) is plotted in blue, and the negative condition (NEG) is plotted in red. The horizontal axis shows the selected time period, and time point 0-ms corresponds to DisP onset. Vertical lines are drawn accordingly to the time-window identified as major area of interest (650ms-1650ms), and used in the statistical analysis below. In this condition, the base probability of target fixation is .25, as there is only one possible referent of the verbal description among the four pictures displayed in the visual scene.

(9) Aladdin is/is not [DisP] closing the door

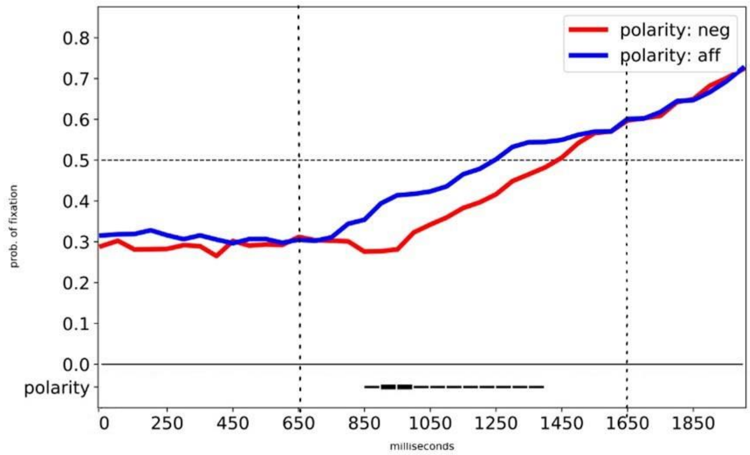


Figure 4.7. Proportion of looks to the target for AFF (blue) and NEG (red) sentences in the condition with one potential target. The black segments at the bottom display the significance of the main effect of *polarity*.

A visual inspection of the graph shows that the target preference arose beyond the chance level (.25) about 100ms after the disambiguation offset for affirmative sentences. Instead, for negative sentences, the increase of fixations towards the target picture started about 300ms after the disambiguation offset. Moreover, the blue line (AFF) is above than the red line (NEG) from 800ms to 1550ms after the disambiguation onset. Overall, this suggests a difference between AFF and NEG conditions with respect to the moment in which the target is disambiguated, as it seems to be identified more quickly in the affirmative condition. Finally, we can observe that, at the onset of the subordinate/coordinate clause, the target picture has been disambiguated regardless of sentence polarity, with the target preference reaching 0.6 for both AFF and NEG sentences: the overlap of the two lines indicates that participants were looking at the same picture (i.e., the target) in both conditions.

We conducted a statistical analysis on the fine-grained time-windows to investigate whether sentence polarity had an influence on the target preference. A Generalized Mixed Model based on the binomial distribution (Jaeger 2008) with *item* and *subject* as random factors and *polarity* as fixed factor has been conducted in each time-slot and for each condition to assess its significance. Target preference was transformed in dummy dichotomous variable: in each trial, it was assigned a value of 1 if greater than 0.5 (i.e., more looks to the target), and of 0 if smaller than 0.5 (i.e., more looks to the competitor). The outcome of this analysis is summarized below in the graph by the presence or absence of small black horizontal segments: a dotted line indicates a quasi-significant effect of *polarity* (p-value between .1 and .05); a solid line indicates a significant effect ($p < .05$), whereas a bold solid segment indicates that the polarity effect was highly significant ($p < .01$). The statistical analysis confirmed that the difference in target preference between AFF and NEG conditions from 850ms to 1400ms is significant, as shown by the presence of a solid segment below the graph in in the time-slots between 900ms and 1000ms. This provides statistical confirmation that the two conditions were different in those time-slots, suggesting the target was disambiguated faster in the AFF condition than in the corresponding NEG one (see Appendix B, Table 4.1)

No other time-slots were revealed significant after 1400ms from the onset of the disambiguation, providing further confirmation of the fact that participants identified the target in both AFF and NEG conditions shortly before the beginning of the subordinate/coordinate clause. To sum up, these results indicate that negative sentences displayed a significant processing penalty in target identification compared to affirmative sentences in the condition with one potential target. In the AFF condition, the target is in fact disambiguated more rapidly.

Two potential targets. The graph in Figure 4.8 depicts the proportion of looks to the target after the Disambiguation Point, computed in 50ms time-slots, for the conditions including two potential targets. The affirmative condition (AFF) is plotted in blue, and the negative condition (NEG) is plotted in red. In this experimental condition, the base probability of target fixation is .50, as there are two possible visual referents of the verbal description out of the four pictures displayed in the visual scene.

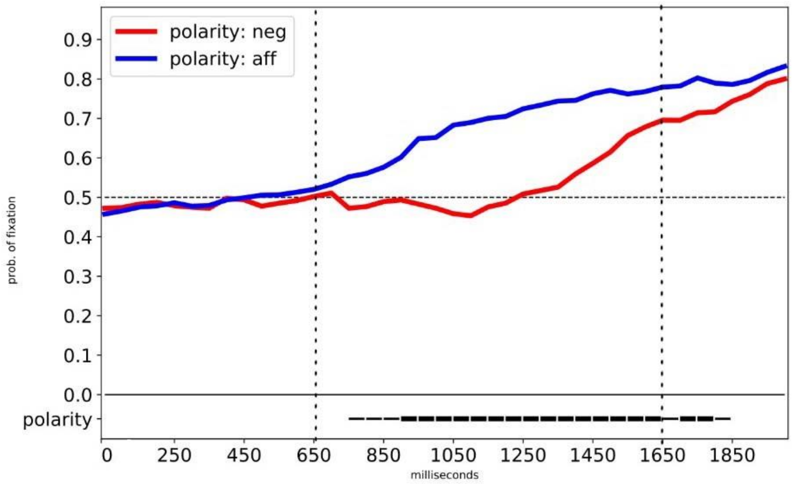


Figure 4.8. Proportion of looks to the target for AFF (blue) and NEG (red) sentences in the condition with two potential targets. The black segments at the bottom display the significance of the main effect of *polarity*.

The graph shows a rapid increase of looks towards the potential targets for the AFF condition, which arose above chance level (.50) immediately after the disambiguation offset. Instead, for the NEG condition, we can see that participants' looks converged towards the target (> .50) only 600ms after the offset of the disambiguation. Moreover, the blue line (AFF) is above than the red line (NEG) from 700ms to 1850ms after the disambiguation onset: this indicates that, at the onset of the subordinate/coordinate clause, participants were looking more steadily at the potential targets in the AFF condition than in the NEG one.

Summarizing, the experimental condition with two potential targets also reveals a difference between AFF and NEG conditions with respect to target disambiguation: again, participants are faster at identifying the target in the AFF condition than in the NEG one. In the latter, there was a greater uncertainty as to which picture (i.e., the target or the competitor) was the referent of the negative sentence, as indicated by the fact that target fixations did not exceed chance level for more than one second from the disambiguation offset, suggesting that participants were equally long looking at the target and the competitor. The statistical analysis confirmed that the difference in target preference between AFF and NEG conditions is significant from 750ms to 1850ms (see Appendix B; Table 4.2). Quite interestingly, four time-slots after the onset of the subordinate/coordinate clause were revealed significant as well. This indicates that: i) the NEG condition displayed a significant processing penalty in target identification compared to the AFF one also in the condition with two potential targets; ii) despite the greater number of potential targets in the visual scenario, this penalty persisted after the onset of the subordinate/coordinate clause.

Finally, if we compare Figure 4.7 and Figure 4.8, it seems that, in our area of interest, the difference between AFF and NEG conditions in target preference is larger in the condition with two potential targets. This aspect will be further investigated with the statistical analysis (§4.3.2.2).

Three potential targets. The graph in Figure 4.9 depicts the proportion of looks to the target after the Disambiguation Point, computed in 50ms time-slots, for the conditions including three potential targets. The affirmative condition (AFF) is plotted in blue, and the negative condition (NEG) is plotted in red. In this experimental condition, the base probability of target fixation is .75, as there are three possible visual referents of the verbal description out of the four pictures displayed in the visual scene.

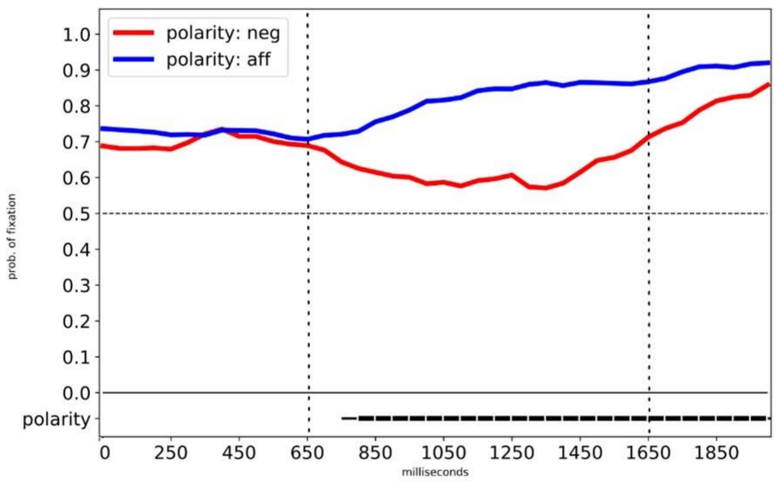


Figure 4.9. Proportion of looks to the target for AFF (blue) and NEG (red) sentences in the condition with three potential targets. The black segments at the bottom display the significance of the main effect of *polarity*.

For affirmative sentences, the graph shows a slight increase in target fixations immediately after the disambiguation offset, reaching.85 at the end of the time-window (1650ms). Instead, we see a pattern of decrease of fixations towards the target for negative sentences: after the disambiguation offset, the target preference drops for about 750ms, reaching about 0.55 at 1400ms in the graph. After 750ms from the disambiguation offset, target fixations start to increase, reaching the initial target preference only at the end of the time-window. However, the blue line (AFF) is above than the red line (NEG) from the disambiguation offset (650ms in the graph) to the end of the time-period included in the graph (2000ms in the graph): this suggests that, even during the unfolding of the subordinate/coordinate clause, participants were looking at the target slightly less often than in the affirmative baseline. The decrease in target fixations in the NEG condition resulted in a significant main effect of *polarity* from 750ms to 2000ms (see Appendix B; Table 4.3). This suggests that the NEG condition displayed a processing penalty in target identification compared to the AFF one also in the condition with three potential targets. Moreover, despite the very high base probability of target fixation in this experimental condition (.75), this processing penalty persisted for about 1250ms, and affected participants' looking pattern behaviour also during the unfolding of the subordinate/coordinate clause.

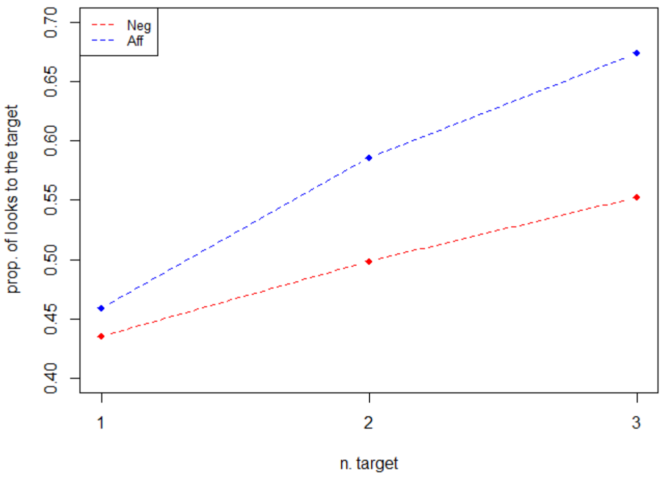
Interestingly, the visual scenario with three potential targets included, for the negative condition, only one picture of the mentioned argument. Quite intuitively, the decrease of target fixations reported for this condition seems to suggest that participants' visual attention was drawn towards the picture corresponding to the negated information. This aspect will be further investigated with the descriptive analyses on the mentioned argument below.

Finally, if we compare the three graphs (Figure 4.7- 4.9), it seems that the difference between AFF and NEG conditions in target identification increases as the number of potential target increases. This finds a preliminary confirmation in the significance of the main effect of *polarity* across conditions, which indicates a greater penalty for target identification in the NEG condition compared to the AFF baseline at the increase of potential targets in the visual scene. This processing penalty will be further investigated with a statistical analysis in the following section.

Statistical analysis on the target

From the previous analysis, it emerged that participants were slower in target identification when presented with negative sentences across experimental conditions. In addition, this delay in target identification in the NEG condition was more pronounced as the number of potential targets increased. In this section, we seek confirmation of whether target identification is affected by sentence polarity, as well as by the interaction between sentence polarity and the number of target pictures displayed in the visual scenario.

Figure 4.10 illustrates the target preference computed over the broad time-window identified as our major area of interest (650ms-1650ms) in the experimental conditions including one, two, and three potential targets. The horizontal axis shows the three experimental conditions, and the vertical axis the absolute proportion of looks to the target(s). The means are reported in the table below the graph. In this analysis, the onset of the time-window was shifted 200ms after the relevant marker in the speech stream for the time it would take to program a saccadic eye movement (Allopenna et al. 1998, Matin et al. 1993). Target preference in the broad time-window was analysed using a linear mixed-effect model with *polarity* (AFF vs. NEG) and *number of targets* (1,2,3) as fixed factors, and *subject* and *item* as random factors. A logarithmic transformation has been applied to the target preference to make it suitable for statistical analysis (Jaeger 2008).



N. target	AFF	NEG
1	.46	.43
2	.58	.49
3	.67	.55

Figure 4.10. Proportion of looks to the target(s) in the broad time-window (650ms-1650ms) for AFF (blue) and NEG (red) conditions including one, two, and three potential targets.

The graph in 4.10 shows a systematic penalty in target identification in the NEG condition compared to the AFF baseline. This results in a significant main effect of *polarity* (β = -0.08, t = -8.66, p < .001), revealing that participants were looking significantly less at the target when presented with negative sentences than with the corresponding affirmative ones. Furthermore, there is a larger difference between AFF and NEG conditions in target preference as the number of potential targets increases. In the condition with one potential target, the target was fixated slightly more often in the AFF condition (0.46) than in the NEG one (0.43). In the condition with two potential targets, the target preference reached 0.58 in the AFF condition but only 0.49 in the NEG one. This difference is still more prominent in the condition with three potential targets: here, despite the higher base probability of target fixations (0.75), in the NEG condition the target preference stopped at 0.55 against the 0.67 in the AFF baseline. This increasing difference led to a significant interaction between *polarity* and *number of targets* (β = -0.05, t = -4,42, p < .001), confirming that participants were looking at the target picture significantly less steadily when presented with NEG sentences than with the corresponding AFF baseline as the number of potential targets increased The analysis yielded also a significant main effect of *number of targets* (β = 0.09, t = 17.60, p < .001). However, this effect is most probably due to the different base probability of target fixations across experimental conditions with one, two, and three potential targets (.25, .50, .75, respectively), and will not be discussed further.

To conclude, this analysis confirms the preliminary observations reported in the descriptive analyses on the target: i) negation always displayed a processing penalty in target identification compared to the affirmative baseline; ii) this penalty for target identification was larger as the number of target pictures increased.

Descriptive analysis on the mentioned argument

The aim of the descriptive analysis on the mentioned argument is to further investigate the effects reported in the previous analyses conducted on the target, which revealed a greater processing penalty for negative sentences, compared to the affirmative baseline, as the number of potential target increases. Crucially, in the negative condition, an increase in the pictures of the potential targets corresponds to a decrease in the pictures of the mentioned argument: while in the affirmative condition the pictures of the mentioned argument correspond in fact to the potential targets, in the negative condition they are the pictures to avoid, as they represent the negated situation. The previous analyses showed, therefore, a facilitating effect for target identification in the negative condition as the number of pictures of the mentioned argument increased. In this last analysis, we seek visual confirmation of whether this effect was driven by participants exploiting the visual representation of the mentioned argument during real-time sentence comprehension.

The graphs in Figure 4.11 depict the proportion of looks to the mentioned argument (MA) after the Disambiguation Point, computed in 50ms time-slots, for the conditions including one (a), two (b), and three (c) pictures of the mentioned argument (i.e., Aladdin closing the door in (10)). The affirmative condition (AFF) is plotted in blue: here, the picture of the mentioned argument represents the target of sentence (10). The negative condition (NEG) is plotted in red: here, the picture of the mentioned argument is the picture to avoid (i.e., the negated state of affairs).

(10) Aladdin is/is not [DisP] closing the door

The horizontal axis shows the selected time period, and time point 0-ms corresponds to the DisP onset. The vertical line indicates the beginning of the broad time-window identified in the previous analyses as our major area of interest. In this analysis, participants' looking pattern behaviour can provide extremely precise information on: i) the exact moment of negation integration into sentence meaning during real-time comprehension; ii) how the visual prominence of the mentioned argument might affect this integration.

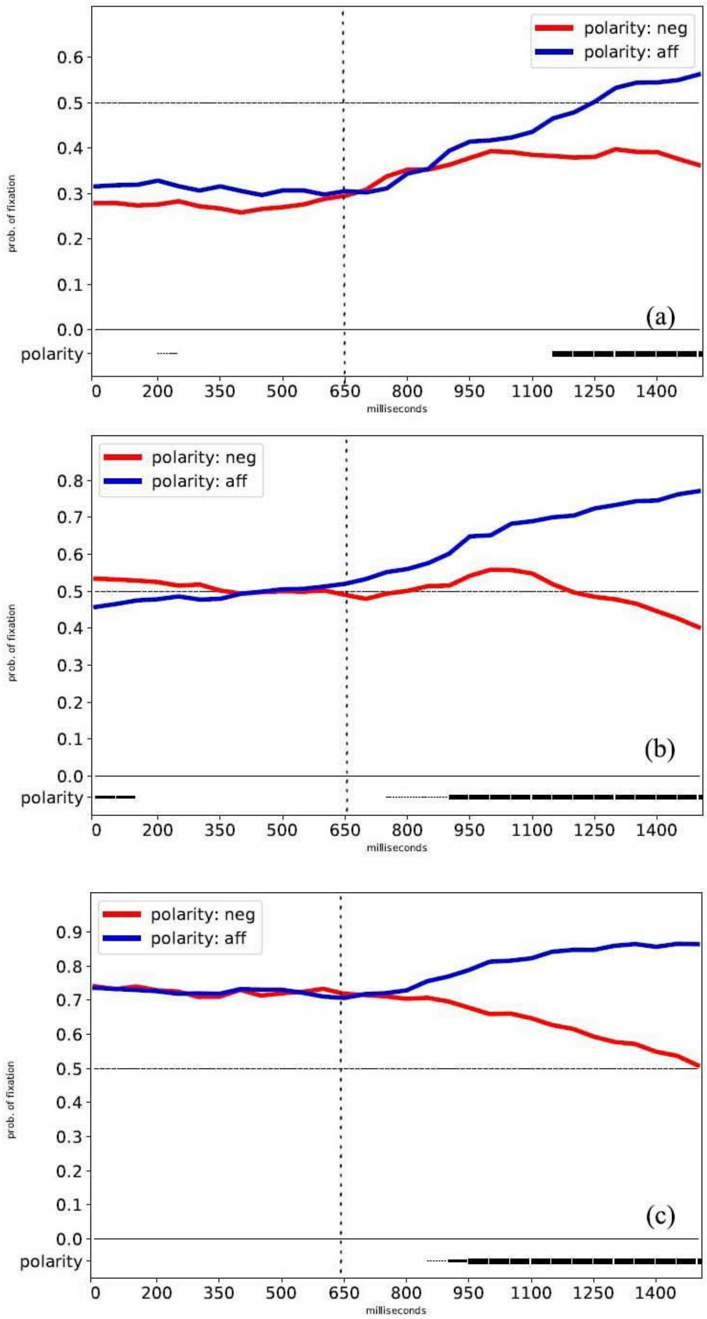


Figure 4.11. Proportion of looks to the mentioned argument (i.e., Aladdin closing the door in (10)) for AFF (blue) and NEG (red) sentences in conditions including one (a), two (b), and three (c) pictures of the mentioned argument. The black segments at the bottom display the significance of the main effect of *polarity*.

One mentioned argument. A visual inspection of graph (4.11a) shows that the blue line (AFF) and the red line (NEG) overlap for about 350ms after the disambiguation offset: this indicates that participants were fixating the picture of the mentioned argument at almost the same rate in both AFF and NEG conditions. At this point, the MA fixations in the AFF condition started to rapidly increase above chance level (.25), suggesting that the target picture has been disambiguated. Instead, in the NEG condition, the MA fixations were stable at 0.35 until 1400ms from the disambiguation onset: then, they started to decrease, indicating that participants were shifting their attention towards the target picture. Note that the NEG condition with one mentioned argument includes three pictures of the potential targets. This means that, despite the very high base probability of target fixation (0.75) in this experimental condition, when presented with negative sentences participants were looking at the picture of the mentioned argument (i.e., the visual competitor) for about 350ms after the offset of the disambiguation, exactly as in the AFF condition. This results in a significant main effect of *polarity* only from 1150ms from the disambiguation onset (see Appendix B; Table 4.10).

Two mentioned arguments. For the condition with two mentioned arguments, graph (4.11b) shows that the blue line (AFF) and the red line (NEG) never overlap after the disambiguation offset. In the AFF condition, there was a rapid increase of MA fixations above chance level (.50), indicating that the target pictures have been rapidly disambiguated. Instead, for the NEG condition, after a slight increase in MA fixations, we see that participants started to shift their gaze away from the pictures of the mentioned argument from about 1100ms. This resulted in a significant main effect of *polarity* from 900ms after the disambiguation onset (see Appendix B; Table 4.11). The time period between 750ms and 900ms was revealed quasi-significant: this suggests that participants were looking less steadily at the pictures of the mentioned argument in the NEG condition than in the AFF one.

If we compare the graphs for the conditions with one (4.11a) and two (4.11b) MA pictures, we can see that, in both conditions, participants were initially looking at the mentioned argument regardless of sentence polarity. However, in the NEG condition with two MA pictures (4.11b), participants were faster in disambiguating the visual referents of the verbal description. In addition, they were looking at the pictures of the mentioned argument slightly less often than in the AFF baseline.

Three mentioned arguments. For the condition with three mentioned arguments, graph (4.11c) shows that the blue line (AFF) and the red line (NEG) overlap only for 200ms. After this point, we can notice an increase of MA fixations in the AFF condition, and a sudden decrease of MA fixations in the NEG one. This resulted in a significant main effect of *polarity* from 900ms after the disambiguation onset – nearly significant at 850ms-900ms (see Appendix B; Table 4.12). Quite intuitively, this pattern of fixations indicates that, in both AFF and NEG conditions, the target has been disambiguated very quickly. Note that the NEG condition with three mentioned arguments includes only one target picture. This means that, despite the very high base probability of MA fixations in this experimental condition(0.75), when presented with NEG sentences, participants took only 200ms to shift their visual attention towards the actual referent of the verbal description after the disambiguation offset.

To conclude, the comparison of the three graphs reveals an advantage in target identification in the NEG condition as the number of pictures of the mentioned argument (i.e., the competitor) increases. This pattern of results provides further confirmation of the effects reported in the previous analyses on the target, which revealed a processing penalty for NEG sentences as the number of potential target increased, compared to the AFF baseline. Moreover, it also confirms our assumption that the decrease of target fixations reported for the NEG condition with three potential targets was due to the fact that participants were looking more steadily at the picture corresponding to the negated information. Taken together, these findings indicates that the visual prominence of the mentioned argument had a facilitating effect on the interpretation process, as negation was integrated faster into sentence meaning when more pictures of the mentioned argument were displayed in the visual scenario.

4.3.2.2 Black and white geometric shapes

Descriptive analysis on the target

One potential target. The graph in Figure 4.12 depicts the proportion of looks to the target after the Disambiguation Point (11), computed in 50ms time-slots, for the conditions including one potential target. The affirmative condition (AFF) is plotted in blue, whereas the negative condition (NEG) is plotted in red. The horizontal axis shows the selected time period, and time point 0-ms corresponds to the DisP onset. Vertical lines are drawn accordingly to the time-window identified as major area of interest (650ms-1650ms), and used in the statistical analysis below. In this condition, the base probability of target fixation is .25, as there is only one possible referent of the verbal description among the four pictures displayed in the visual scene.

(11) There is/is not [DisP] a pentagon

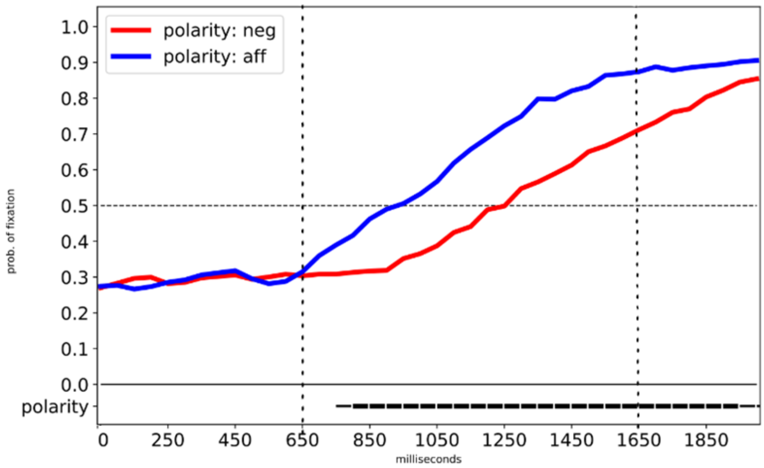


Figure 4.12. Proportion of looks to the target for AFF (blue) and NEG (red) sentences in the condition with one potential target. The black segments at the bottom display the significance of the main effect of *polarity*.

The graph shows a rapid increase of target fixations beyond chance level (.25) immediately after the disambiguation offset for affirmative sentences. Instead, for negative sentences, target fixations arose above chance level only about 250ms after the disambiguation offset. In addition, the absolute proportion of looks to the target is always higher in the AFF condition than in the NEG one, as indicated by the fact that the blue line (AFF) is above the red line (NEG) for the entire broad time-window (650ms-1650ms). Quite interestingly, this advantage in target preference for the AFF condition persists until the end of the time period included in the graph (2000ms). Taken together, these results reveal a difference between AFF and NEG conditions with respect to the moment in which the target is disambiguated, with NEG showing a processing penalty in comparison to the AFF baseline. Moreover, in the NEG condition participants were looking at the target less steadily than in the AFF baseline even after target disambiguation (i.e., after the increase in target fixations). For instance, at the end of our broad time-window, the target preference reached 0.85 for AFF and 0.7 for NEG.

The statistical analysis showed that the difference in target preference between AFF and NEG conditions is significant from 750ms to 800ms, and highly significant between 800ms and 1650ms. In addition, the time-slots in the final time-window were also revealed highly significant until 1950ms (see Appendix B; Table 4.4). This suggests that the NEG condition displayed a processing penalty in target identification compared to the AFF baseline. In other words, participants were slower at identifying the target when presented with the negative sentence.

Two potential targets. The graph in Figure 4.13 depicts the proportion of looks to the target after the Disambiguation Point, computed in 50ms time-slots, for the conditions including two potential targets. The affirmative condition (AFF) is plotted in blue, and the negative condition (NEG) is plotted in red. Vertical lines are drawn accordingly to the time-window identified as our major area of interest (650ms-1650ms). In this condition, the base probability of target fixation is .50, as there are two possible visual referents of the verbal description out of the four pictures displayed in the visual scene.

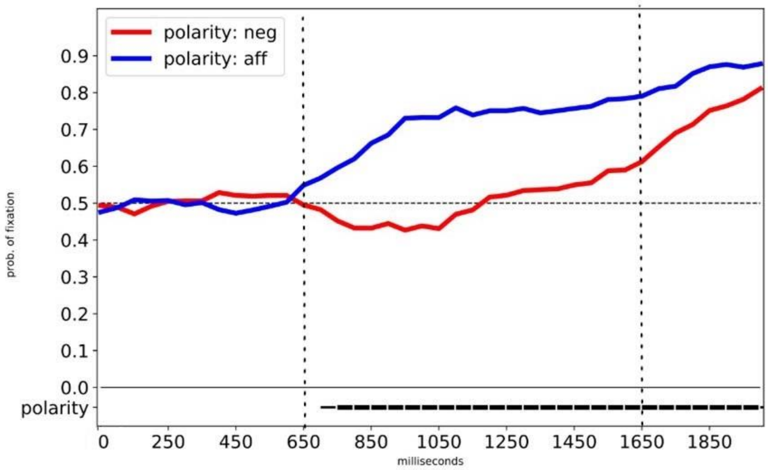


Figure 4.13. Proportion of looks to the target for AFF (blue) and NEG (red) sentences in the condition with two potential targets. The black segments at the bottom display the significance of the main effect of *polarity*.

The graph shows a prominent increase of the target preference above chance level (.50) in the AFF condition immediately after the disambiguation offset. Instead, in the NEG condition, the proportion of looks towards the target slightly decreased below chance level after the offset of the disambiguation, with the participants' looks converging towards the target (> .50) only 600ms later (at 1250ms in the graph). Moreover, the blue line (AFF) is above the red line (NEG) for the entire broad time-window, at the end of which the target preference reached 0.8 for AFF and 0.6 for NEG. In addition, participants were looking more steadily at the potential targets in the AFF condition than in the NEG one also after the onset of the subordinate/coordinate clause, as indicated by the higher target preference in the AFF condition persisting until the end of the time period included in the graph.

Again, it seems that participants were faster in target identification when presented with affirmative sentences in the experimental condition with two potential targets as well. The statistical analysis revealed that the difference in target preference between AFF and NEG conditions is significant from 700ms to 750ms, and highly significant between 750ms and 1650ms. In addition, the subsequent time-slots were also revealed highly significant until 2000ms (see Appendix B; Table 4.5). This seems to indicate that the NEG condition displayed a significant penalty in target identification, compared to the AFF baseline. Moreover, we also noted that this processing penalty persisted after the onset of the subordinate/coordinate clause.

Finally, if we compare Figure 4.12 and Figure 4.13, it seems that, in our area of interest, the difference between AFF and NEG conditions in target preference is more prominent in the condition with two potential targets. This aspect will be further investigated with the statistical analysis below.

Three potential targets. The graph in Figure 4.14 depicts the proportion of looks to the target after the Disambiguation Point, computed in 50ms time-slots, for the conditions including three potential targets. The affirmative condition (AFF) is plotted in blue, and the negative condition (NEG) is plotted in red. Vertical lines are drawn accordingly to the time-window identified as our major area of interest (650ms-1650ms). In this condition, the base probability of target fixation is .75, as there are three possible visual referents of the verbal description out of the four pictures displayed in the visual scene.

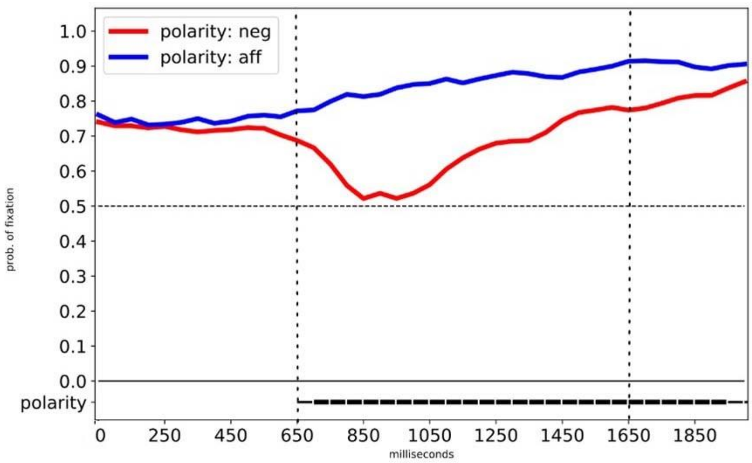


Figure 4.14. Proportion of looks to the target for AFF (blue) and NEG (red) sentences in the condition with three potential targets. The black segments at the bottom display the significance of the main effect of *polarity*.

For affirmative sentences, the graph shows an increase of target fixations immediately after the disambiguation offset, that reached 0.9 at the end of the broad time-window. Instead, for negative sentences we see a highly pronounced decrease of target fixations: after the disambiguation offset, the target preference drops below chance level (.75) for about 400ms, reaching 0.5 at 1000ms. At this point, the absolute proportion of looks to the target is 0.5 for NEG and 0.85 for AFF. After 400ms from the disambiguation offset (at 1050ms in the graph), target fixations started to increase again in the NEG condition, reaching the initial target preference at about 1450ms. However, the blue line (AFF) is above the red line (NEG) for the entire broad time-window: this reveals an advantage in target preference for the AFF condition compared to the NEG one, that persists during the unfolding of the subordinate/coordinate clause (from 1650ms onwards). The sudden decrease of target fixations in the NEG condition resulted in a significant main effect of *polarity* from 650ms to 700ms, which becomes highly significant between 700ms and 1650ms. Quite interestingly, the time-slots after the onset of the subordinate/coordinate clause were also revealed highly significant until 1950ms (see Appendix B; Table 4.6). This indicates that, despite the very high base probability of target fixation, the NEG condition displayed a processing penalty in target identification compared to the AFF baseline. In addition, this penalty affected participants' looking pattern behaviour also after the offset of the target sentence.

As discussed for cartoon characters, the decrease of target fixations reported for the NEG condition including three potential targets seems to suggest that participants were looking more often than in the AFF baseline at the fourth picture displayed in the visual scene, that is, the picture of the mentioned argument. This aspect will be further investigated with the descriptive analyses on the mentioned argument below.

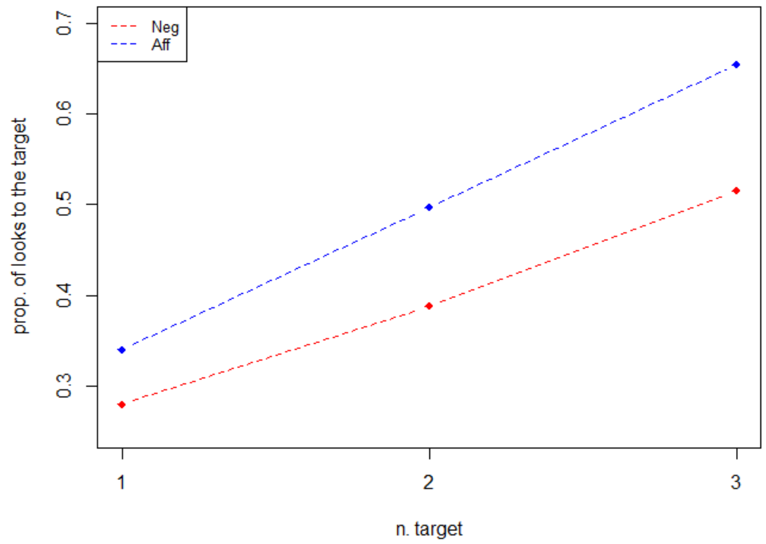
To conclude, if we compare the three graphs (Figure 4.12 - 4.14), it seems that, in our area of interest, the difference between AFF and NEG conditions in target preference is more pronounced as the number of potential target increases. This finds a preliminary confirmation in the main effect of *polarity* reported across conditions, which affects more time-slots, and more significantly, at the increase of the potential targets in the visual scene. This processing penalty will be further investigated with a statistical analysis in the following section.

Finally, very similar patterns of fixations were also reported in the descriptive analyses on the target for cartoon characters (§4.3.2.1). This aspect of negation processing will be discussed in §4.4.4

Statistical analysis on the target

The previous analysis revealed that the NEG condition displayed a processing penalty in target identification compared to the AFF baseline regardless of the number of potential targets displayed in the visual scenario. Moreover, this penalty worsened at the increase of the target pictures. In this section, we seek confirmation of whether target identification is significantly affected by sentence polarity, as well as by the interaction between sentence polarity and the number of potential targets.

Figure 4.15 illustrates the target preference computed over the broad time-window identified as our major area of interest (650ms-1650ms) in the experimental conditions including one, two, and three potential targets. The horizontal axis shows the three experimental conditions, and the vertical axis the absolute proportion of looks to the target(s). The means are reported in the table below the graph. The AFF condition is plotted in blue, and the NEG condition is plotted in red. In this analysis, the onset of the time-window was shifted 200ms after the relevant marker in the speech stream to account for saccade programming (Allopenna et al. 1998, Matin et al. 1993). Target preference in the broad time-window was analysed using a linear mixed-effect model with *polarity* (AFF vs. NEG) and *number of targets* (1,2,3) as fixed factors, and *subject* and *item* as random factors. A logarithmic transformation has been applied to the target preference to make it suitable for statistical analysis (Jaeger 2008).



N. target	AFF	NEG
1	.34	.28
2	.50	.39
3	.65	.52

Figure 4.15. Proportion of looks to the target(s) in the broad time-window (650ms-1650ms) for AFF (blue) and NEG (red) conditions including one, two, and three potential targets.

The graph in 4.15 shows an overall advantage in target identification for the AFF conditions in comparison the NEG ones, resulting in a significant main effect of *polarity* (β = -0.10 , t = -8.94, $p < .001$). This provides statistical confirmation that participants were remarkably slower in target identification when presented with negative sentences than with the corresponding affirmative ones. Moreover, the difference between AFF and NEG conditions becomes more prominent at the increase in the number of potential targets. In the condition with one potential target, the proportion of looks to the target was slightly higher in the AFF condition (0.34) than in the NEG one (0.28). In the condition with two potential targets, the target preference was 0.50 for the AFF condition and 0.39 for the NEG one. Despite the higher base probability of target fixation, in the NEG condition with three potential targets, participants were looking at the target picture substantially less often than in the AFF baseline: the target preference stopped at 0.52 with negative sentences against the 0.65 with the corresponding affirmative ones. This overall pattern of fixations resulted in a highly significant interaction between *polarity* and *number of targets* (β = -0.04, t = -2.84, $p < .001$), confirming that, at the increase in the number of potential targets, participants were looking at the target picture significantly less often in the NEG condition than in the corresponding AFF baseline. The *number of targets* was also revealed highly significant (β = 0.14, t = 19.83, $p < .001$). However, as already pointed out in the statistical analysis with cartoon characters (§4.3.2.1), the reported effect can be the consequence of a different base probability of target fixation across the experimental conditions with one, two, and three potential targets (.25, .50, .75, respectively).

To conclude, these findings confirm the preliminary observations reported in the previous descriptive analysis on the target regarding two main aspects of negation processing. First, participants were always faster in target identification when presented with affirmative sentences than with the corresponding negative ones. Second, this processing penalty conveyed by negation increased as the number of target pictures increased. Worth noting, the same effects were also reported in the statistical analysis on the target for cartoon characters (§4.3.2.1): we leave the discussion of more general features of negation processing for section §4.4.4.

Descriptive analysis on the mentioned argument

The previous analyses on target showed a greater processing penalty for negative sentences compared to the affirmative baseline as the number of potential targets increases. Note that, as the number of potential targets increases, the number of pictures of the mentioned arguments increases in the affirmative condition but it decreases in the negative one. It follows that, in the negative condition, participants were faster in target identification when more pictures of the mentioned argument (i.e., competitors) were displayed in the visual scene. The current analysis aims to investigate whether this effect can be related to possible patterns of fixations towards the picture(s) of the mentioned argument.

The graphs in Figure 4.16 depict the proportion of looks to the mentioned argument (MA) after the Disambiguation Point (12) for the conditions including one (a), two (b), and three (c) pictures of the mentioned argument (i.e., the pentagon in (12)). The affirmative condition (AFF) is plotted in blue: here, the picture of the mentioned argument represents the target of sentence (12). The negative condition (NEG) is plotted in red: here, the picture of the mentioned argument is the picture to avoid (i.e., the negated state of affairs).The horizontal axis shows the selected time period, and time point 0-ms corresponds to the DisP onset. The vertical line indicates the beginning of the broad time-window identified in the previous analyses as our major area of interest.

(12) There is/is not [DisP] a pentagon

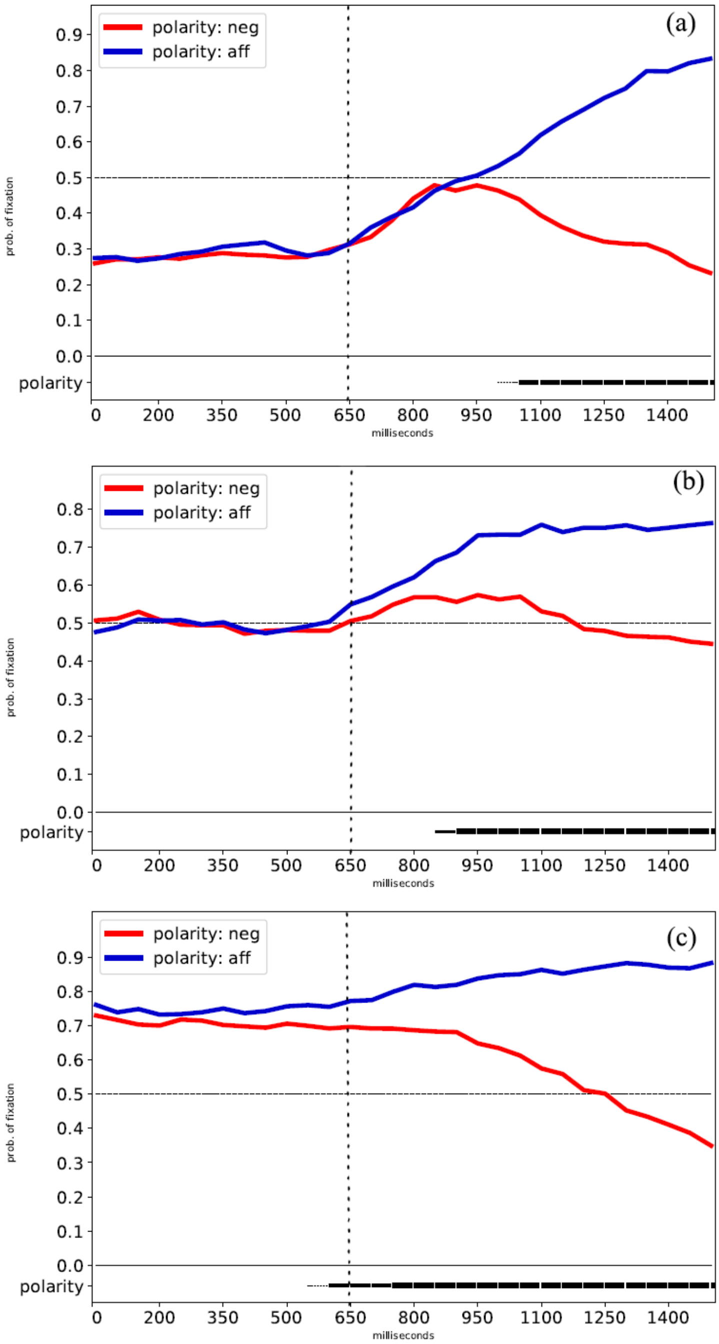


Figure 4.16. Proportion of looks to the mentioned argument (i.e., the pentagon in (12)) for AFF (blue) and NEG (red) sentences in conditions including one (a), two (b), and three (c) pictures of the mentioned argument. The black segments at the bottom display the significance of the main effect of *polarity*.

One mentioned argument. For the condition with one mentioned argument, graph (4.16a) shows that the blue line (AFF) and the red line (NEG) exactly overlap for about 300ms after the disambiguation offset. This suggests that participants were looking at the picture of the mentioned argument in both the AFF and the NEG conditions: however, while in the former the mentioned argument corresponded to the target, in the latter it represented the picture to avoid. At about 950ms in the graph, we see that the MA fixations increased in the AFF condition, indicating that the target picture has been disambiguated. Conversely, we notice a rapid decrease of looks to the mentioned argument in the NEG condition, indicating that participants were shifting their gaze towards the actual target of the negative sentence only at this point of the speech stream. Note that, in the NEG condition with one mentioned argument, the base probability of being already fixating one of the three potential targets at the sentence onset was 0.75. Nonetheless, participants were looking at the picture of the mentioned argument (i.e., the competitor) at the same rate as in the AFF baseline for about one second from the disambiguation onset. This finds statistical confirmation in the fact that the effect of *polarity* was revealed significant only from 1050ms after the disambiguation onset – nearly significant in the time-slot 1000ms-1050ms (see Appendix B; Table 4.13)

Two mentioned arguments. For the condition with two mentioned arguments, graph (4.16b) shows that the blue line (AFF) and the red line (NEG) never overlap after the disambiguation offset. Nonetheless, in both conditions we can see an increase of fixations towards the mentioned argument. In the AFF condition, the increase of MA fixations was quite rapid and constant, indicating that participants have made a decision towards the target picture. Instead, in the NEG condition, we initially see a slight increase in MA fixations until about 400ms from the offset of the disambiguation (at 1050ms in the graph). At this point in the speech stream, the MA fixations started to decrease, indicating that participants have disambiguated the target picture also in the NEG condition. A significant effect of *polarity* was reported only from 850ms after the disambiguation onset – highly significant from 900ms (see Appendix B; Table 4.14). This indicates that the NEG condition displayed a significant penalty in target identification compared to the AFF baseline also in the condition with two mentioned arguments.

The comparison between the conditions with one (4.16a) and two (4.16b) MA pictures reveals that, in both conditions, the participants' visual attention was initially drawn towards the MA pictures regardless of sentence polarity. This pattern of fixations clearly indicates a delay in target identification for the NEG condition. However, this processing penalty was smaller in the condition with 2 MA pictures: here, participants were faster in disambiguating the actual target of the negative sentence, as also revealed by a lower rate of MA fixations after the disambiguation offset in comparison to the AFF baseline.

Three mentioned arguments. For the condition with three mentioned arguments, graph (4.16c) shows that the blue line (AFF) and the red line (NEG) do not overlap after the disambiguation offset. However, in contrast to what observed in the condition with two mentioned arguments (graph in 4.16b), we can observe an opposite pattern of MA fixations for the AFF and the NEG conditions immediately after the disambiguation offset. While in the AFF condition there was an increase in MA fixations, in the NEG condition the MA fixations began to slowly decrease until 900ms in the graph, when the decrease became more consistent. Moreover, a closer visual inspection of the graph reveals that these different patterns of MA fixations in the two polarity conditions already began during the unfolding of the critical word, at about 500ms from the disambiguation onset. This resulted in a significant effect of *polarity* from 600ms after the disambiguation onset – highly significant from 750ms (see Appendix B; Table 4.15). Moreover, the time-slot 550ms-600ms was also revealed nearly significant. All in all, this provides statistical confirmation that the target has been disambiguated very quickly in both AFF and NEG conditions. Quite interestingly, as concerns the NEG condition, this occurs in an experimental condition in which there was a very high base probability of fixating the mentioned argument (0.75).

To conclude, the comparison of the three graphs in Figure 4.16 reveals an important advantage in target identification in the NEG condition as the number of pictures of the mentioned argument (i.e., the competitor) increased. Taken together, these findings confirm the effects reported in the previous analyses on the target: i) in the NEG condition, the more the pictures of the potential target in the visual scenario, the slower participants were in target identification compared to the AFF baseline; ii) the decrease in target fixations reported for the NEG condition with three potential targets can be traced back to the fact that participants were initially looking more steadily at the picture of the mentioned argument. Altogether, this evidence speaks in favour of a facilitating effect of the visual prominence of the mentioned argument on the interpretation process: negation was integrated faster into sentence meaning when more pictures of the mentioned argument were depicted in the visual scene, as revealed by the fact that participants were faster in shifting their gaze towards the actual target of the negative sentence.

Finally, very similar patterns of fixations towards the mentioned argument were also reported in the descriptive analyses with cartoon characters (§4.3.2.1). This and other similarities in the processing of negative sentences across the different types of items will be discussed in §4.4.

4.3.2.3 Coloured geometric shapes

Descriptive analysis on the target

One potential target. The graph in Figure 4.17 depicts the proportion of looks to the target after the Disambiguation Point (13), computed in 50ms time-slots, for the conditions including one potential target. The affirmative condition (AFF) is plotted in blue, whereas the negative condition (NEG) is plotted in red. The horizontal axis shows the selected time period, and time point 0-ms corresponds to DisP onset. Vertical lines are drawn accordingly to the time-window identified as major area of interest (650ms-1650ms), and used in the statistical analysis below. In this condition, the base probability of target fixation is .25, as there is only one possible referent of the verbal description among the four pictures displayed in the visual scene.

(13) The triangle is/is not [DisP] green

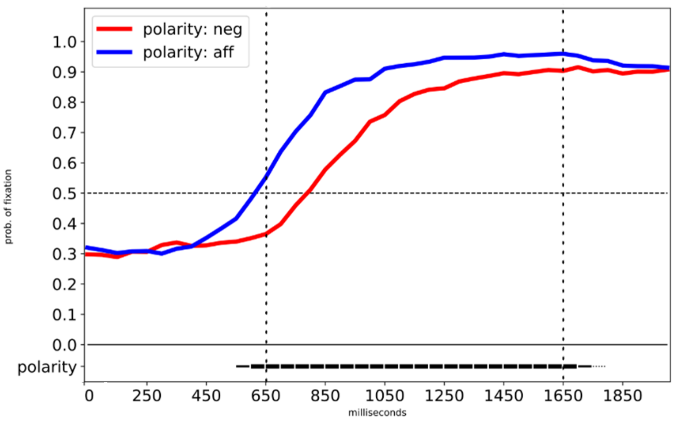


Figure 4.17. Proportion of looks to the target for AFF (blue) and NEG (red) sentences in the condition with one potential target. The black segments at the bottom display the significance of the main effect of *polarity*.

The graph shows a rapid increase of target fixations immediately after the disambiguation offset for both affirmative and negative sentences. However, a closer visual inspection reveals that, in the AFF condition, the target preference started to arise above chance level (.25) before the onset of our major area of interest, that is, during the unfolding of the critical word (at about 450ms in the graph).. Instead, in the NEG condition, target fixations started to increase above chance level immediately after the offset of the disambiguation (650ms in the graph). All in all, this indicates that participants disambiguated the target very quickly regardless of sentence polarity . Nonetheless, the absolute proportion of looks to the target is always higher in the AFF condition (blue line) than in the NEG one (red line) for the entire broad time-window (650ms-1650ms). This different gaze pattern, together with the fact that the increase of target fixations is delayed in the NEG condition by about 200ms, implies that participants were slower in target identification when presented with negative sentences. Quite interestingly, we can observe that, at the end of the broad time-window, the two lines almost overlap, with target preference reaching about 0.9 in both conditions. This result indicates that the target picture has been disambiguated with both AFF and NEG sentences by the offset of the target sentence (13).

The statistical analysis revealed that the difference in target preference between AFF and NEG conditions is highly significant for the entire broad time-window (650ms-1650ms). The time-slot 600ms-650ms was also revealed significant, as well as the time-slots between 1650ms and 1750ms (see Appendix B; Table 4.7). This result indicates that: i) the target is disambiguated very quickly in both AFF and NEG conditions; ii) the NEG condition displayed a significant processing penalty in target identification, compared to the AFF baseline.

Two potential targets. The graph in Figure 4.18 depicts the proportion of looks to the target after the Disambiguation Point, computed in 50ms time-slots, for the conditions including two potential targets. The affirmative condition (AFF) is plotted in blue, and the negative condition (NEG) is plotted in red. The horizontal axis shows the selected time period, and time point 0-ms corresponds to DisP onset. Vertical lines are drawn accordingly to the time-window identified as major area of interest (650ms-1650ms), and used in the statistical analysis below. In this experimental condition, the base probability of the target fixation is .50, as there are two possible visual referents of the verbal description out of the four pictures displayed in the visual scene.

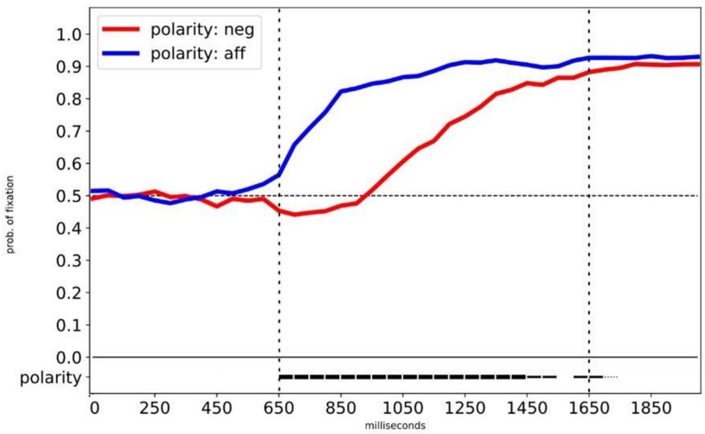


Figure 4.18. Proportion of looks to the target for AFF (blue) and NEG (red) sentences in the condition with two potential targets. The black segments at the bottom display the significance of the main effect of *polarity*.

The graph shows a rapid increase of target fixations above chance level (.50) in the AFF condition immediately after the disambiguation offset. However, we note that the target preference started to arise before the onset of our major area of interest, at about 500ms after the onset of the critical word. Instead, we can notice a slight decrease in target fixations in the NEG condition (< 0.45) that lasted for about 200ms after the disambiguation offset. Only at this point, the target preference started to rapidly increase also for negative sentences, exceeding chance level (.50) at about 400ms after the offset of the disambiguation (at 1050ms in the graph), and reaching about 0.85 for both AFF and NEG conditions at the end of the broad time-window. This implies that the target picture has been disambiguated with both AFF and NEG sentences by the onset of the subordinate/coordinate clause. Nonetheless, the blue line (AFF) is above the red line (NEG) for the entire broad time-window (650ms-1650ms): for instance, when target preference starts to increase for negative sentences (850ms), the absolute proportion of looks to the target is about 0.45 for the NEG condition and 0.8 for the AFF baseline. Crucially, these results indicate that participants were slower in target identification when presented with negative sentences also in the condition with two potential targets.

The statistical analysis confirmed that the difference in target preference between AFF and NEG conditions is highly significant from 650ms to 1450ms. A main effect of *polarity* ($p < .05$) has been reported also from 1450ms to 1550ms, and from 1600ms to 1700ms (see Appendix B; Table 4.8). This suggests that, despite the greater number of potential targets in the visual scenario, the NEG condition displayed a significant processing penalty in target identification compared to the AFF baseline. Moreover, the target picture is disambiguated quite fast in both conditions, as this penalty did not persist after the onset of the subordinate/coordinate clause.

Finally, if we compare Figure 4.17 and Figure 4.18, it seems that, in our area of interest, the difference between AFF and NEG conditions in target preference is more pronounced in the condition with two potential targets. This aspect will be further investigated with the statistical analysis below.

Three potential targets. The graph in Figure 4.19 depicts the proportion of looks to the target after the Disambiguation Point, computed in 50ms time-slots, for the conditions including three potential targets. The affirmative condition (AFF) is plotted in blue, whereas the negative condition (NEG) is plotted in red. The horizontal axis shows the selected time period, and time point 0-ms corresponds to DisP onset. Vertical lines are drawn accordingly to the time-window identified as major area of interest (650ms-1650ms), and used in the statistical analysis below. In this experimental condition, the base probability of the target fixation is .75, as there are three possible visual referents of the verbal description out of the four pictures displayed in the visual scene.

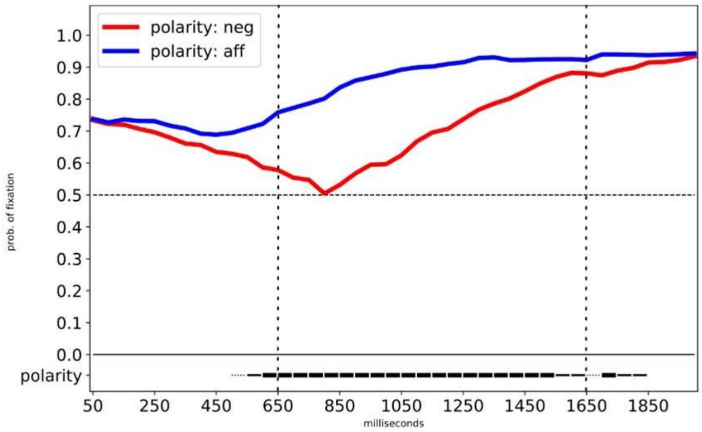


Figure 4.19. Proportion of looks to the target for AFF (blue) and NEG (red) sentences in the condition with three potential targets. The black segments at the bottom display the significance of the main effect of *polarity*.

The graph shows an opposite pattern of target fixations for the AFF and the NEG conditions at the disambiguation offset. While there was a consistent increase of target preference in the AFF condition, we can see that target fixations rapidly decreased below chance level (.75) in the NEG one, dropping to 0.5 at 150ms after the disambiguation offset. At this point in the speech stream (800ms), the target preference arose again also for negative sentences, reaching about 0.90 for both AFF and NEG conditions at the end of the broad time-window. However, the absolute proportion of looks to the target in the AFF condition (blue line) is higher than in the NEG condition (red line) for the entire broad time-window: for instance, when target preference starts to increase for negative sentences (at 800ms in the graph), the absolute proportion of looks to the target is about 0.5 for the NEG condition and 0.8 for the AFF baseline. Taken together, these results indicate a penalty in target identification for the NEG condition compared to the AFF baseline also in the condition with three potential targets. Furthermore, it is worth noting that, as in the conditions with one and two potential targets, participants' looking pattern behaviour already affected the target preference during the unfolding of the critical word: target fixations started to increase at about 400ms in the AFF condition, and to decrease at about 300ms in the NEG one. This, together with the fact that the penalty in target identification for the NEG condition did not persist during the unfolding of the subordinate/coordinate clause, shows that the target picture is disambiguated quite fast in both AFF and NEG conditions.

The rapid decrease of target fixations in the NEG condition resulted in a highly significant effect of *polarity* from 650ms to 1550ms (see Appendix B; Table 4.9). A main effect of *polarity* ($p < .05$) has been reported also from 1550ms to 1650ms. In addition, two time-slots before the beginning of our broad time-window were also revealed significant (550ms-650ms, highly significant from 600ms to 650ms), and a quasi-significant effect of *polarity* has been reported from 500ms to 550ms.

The time-slots after the onset of the subordinate/coordinate clause were also revealed significant from 1700ms to 1850ms (highly significant in the first 50ms-slot). This provides statistical confirmation that the two polarity conditions are different in those time-slots, and suggests that the NEG condition displayed a significant processing penalty in target identification compared to the affirmative baseline. In addition, participants were looking more steadily at the potential targets in the AFF condition than in the NEG one also after that the target picture had been disambiguated.

As discussed for the other types of stimuli employed in the task, the robust decrease of target fixations reported for this NEG condition seems to indicate that participants, after the onset of the critical word, were focusing their visual attention towards the fourth picture displayed in the visual scene, that is, the picture of the mentioned argument for about 850ms. This aspect will be further investigated with the descriptive analyses on the mentioned argument below.

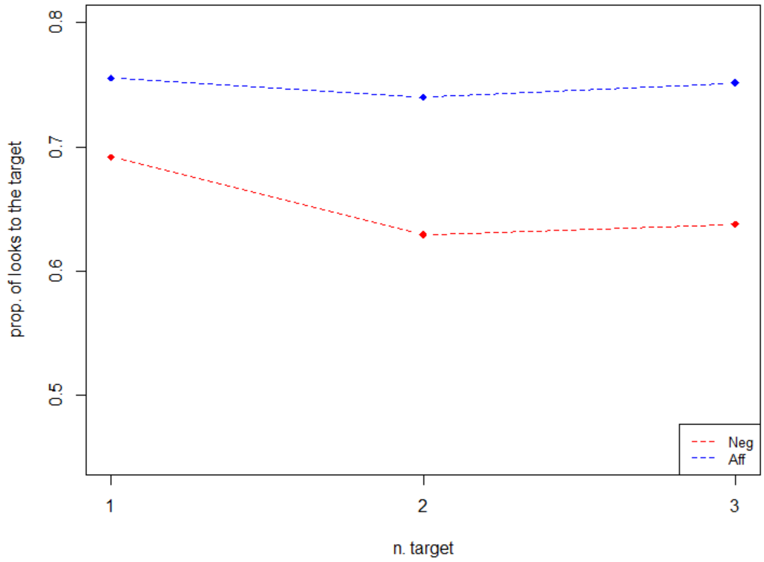
Finally, if we compare the three graphs (Figure 4.17 - 4.19), it seems that, in our area of interest, the difference between AFF and NEG conditions in target preference is more pronounced in the conditions with two and three potential targets than in the condition with only one target picture. However, this difference seems minimal, at least visually, between the conditions with two and three potential targets. This processing penalty will be further investigated with a statistical analysis in the following section.

To conclude, very similar patterns of fixations were also reported for cartoons characters (§4.3.2.1) and for black and white geometric shapes (§4.3.2.2), pointing to an overall penalty in target identification for NEG sentences compared to the affirmative baselines that increases at the increase in the number of potential targets. In addition, the NEG condition with three potential targets is characterized by an initial drop of target fixations: this decrease is more robust with coloured and black and white geometric shapes but is also visible with cartoon characters. These common aspects underlying negation processing will be further discussed in §4.4.4.

Statistical analysis on the target

The previous analyses suggested that participants were slower in target identification in all the three NEG conditions compared to the corresponding AFF ones. The difference in target preference was more pronounced in the conditions with two and three potential targets than in the condition with only one target picture. Moreover, this penalty seemed unvaried in the NEG conditions with two and three target pictures. In this section, we will further investigate how sentence polarity and its interaction with the number of target pictures affect the process of target identification.

Figure 4.20 shows the target preference computed over the broad time-window which corresponds to our major area of interest (650ms-1650ms) in the experimental conditions including one, two, and three potential targets. The horizontal axis shows the three experimental conditions, and the vertical axis the absolute proportion of looks to the target(s). The means are reported in the table below the graph. The AFF condition is plotted in blue, and the NEG condition is plotted in red. In this analysis, we shifted the onset of the time-window 200ms after the relevant marker in the speech stream to account for saccade programming (Allopenna et al. 1998, Matin et al. 1993). Target preference in the broad time-window was analysed using a linear mixed-effect model with *polarity* (AFF vs. NEG) and *number of targets* (1,2,3) as fixed factors, and *subject* and *item* as random factors. A logarithmic transformation has been applied to the target preference to make it suitable for statistical analysis (Jaeger 2008).



N. target	AFF	NEG
1	.78	.69
2	.74	.63
3	.75	.64

Figure 4.20. Proportion of looks to the target(s) in the broad time-window (650ms-1650ms) for AFF (blue) and NEG (red) conditions including one, two, and three potential targets.

The graph in 4.20 shows an overall penalty in target identification in the NEG condition compared to the AFF baseline, regardless of the number of target pictures displayed in the visual scenario. This resulted in a highly significant main effect of *polarity* (β = -0.09 , t = -11.66, $p < .001$), confirming that participants were looking significantly more often at the target picture when presented with affirmative sentences than with the corresponding negative ones. In the condition with one potential target, the proportion of looks to the target was slightly higher in the AFF condition (0.78) than in the NEG one (0.69). Despite a higher base probability of target fixation, the processing penalty conveyed by negation was greater in the conditions with two and three potential targets than in the condition with only one target picture. Besides being more prominent, the difference in target fixations between AFF and NEG conditions was constant when two and three potential targets were displayed in the visual scene: 0.74 vs. 0.63 with two target pictures, and 0.75 vs. 0.64 with three target pictures, respectively. This overall pattern of fixations resulted in a significant interaction between *polarity* and *number of targets* (β = -0.02, t = -2.53, p = < .01), confirming that, at the increase in the number of potential targets, participants were looking at the target picture significantly less often when presented with negative sentences than with the corresponding affirmative ones. The *number of targets* was also revealed significant (β = 0.01, t = -2.81, p < .01), indicating that participants were looking more often at the target picture as the number of target pictures displayed in the visual scenario increased. As already pointed out in the statistical analyses with cartoon characters (§4.3.2.1) and black and white geometric shapes (§4.3.2.2), this effect might be related to the different base probability of target fixations across experimental conditions. However, we can observe a slightly lower target preference in the conditions with two and three target pictures, even though in these conditions participants were more likely to be already fixating one of the potential targets at the sentence onset. This evidence is in line with the patterns of fixations reported in the descriptive analysis on the target, showing a decrease in target fixations in the NEG conditions with two and three potential targets – extremely pronounced in the latter.

Note that the proportion of looks to the target reported for both AFF and NEG conditions is always higher than .60 regardless of the number of target pictures. This is in line with what observed in the descriptive analysis on the target: even though participants were slower in target identification when presented with negative sentences, the target has been disambiguated very quickly in both AFF and NEG conditions.

To conclude, these findings confirm the effects reported in the previous analysis regarding two main aspects of the processing: first, participants were always slower in target identification when presented with negative sentences than with the corresponding affirmative ones; second, this processing penalty was greater in the conditions with two and three target pictures. Although these effects were also reported in the statistical analysis on the target for cartoon characters (§4.3.2.1) and black and white geometric shapes (§4.3.2.2), they are less prominent with coloured geometric shapes, as indicated by: i) a higher target preference in the three NEG conditions; and ii) a constant processing penalty conveyed by negation in the conditions with two and three target pictures. All in all, this indicates that negation was processed very fast with coloured geometric shape items, suggesting that negation processing might be sensitive to linguistic and perceptual features of visually presented stimuli.

Descriptive analysis on the mentioned argument

The previous analyses on the target revealed a greater processing penalty for negative sentences compared to the affirmative baseline when two and three potential targets were displayed in the visual scene. Note that the ratio between the number of potential targets and the number of pictures of the mentioned argument is directly proportional in the affirmative condition, but inversely proportional in the negative one. Therefore, in the negative condition, participants were faster in target identification when more pictures of the mentioned argument (i.e., competitors) were present in the visual scene. The aim of this last exploratory analysis is to assess whether such an effect was driven by possible patterns of fixations towards the picture(s) of the mentioned argument.

The graphs in Figure 4.21 depict the proportion of looks to the mentioned argument (MA) after the disambiguation point (14) for the conditions including one (a), two (b), and three (c) pictures of the mentioned argument (i.e., the green triangle in (14)). The affirmative condition (AFF) is plotted in blue: here, the picture of the mentioned argument represents the target of sentence (14). The negative condition (NEG) is plotted in red: here, the picture of the mentioned argument is the picture to avoid (i.e., the negated state of affairs). The horizontal axis shows the selected time period, and the time point 0-ms corresponds to the DisP onset. The vertical line indicates the beginning of the broad time-window identified in the previous analyses as our major area of interest.

(14) The triangle is/is not [DisP] green

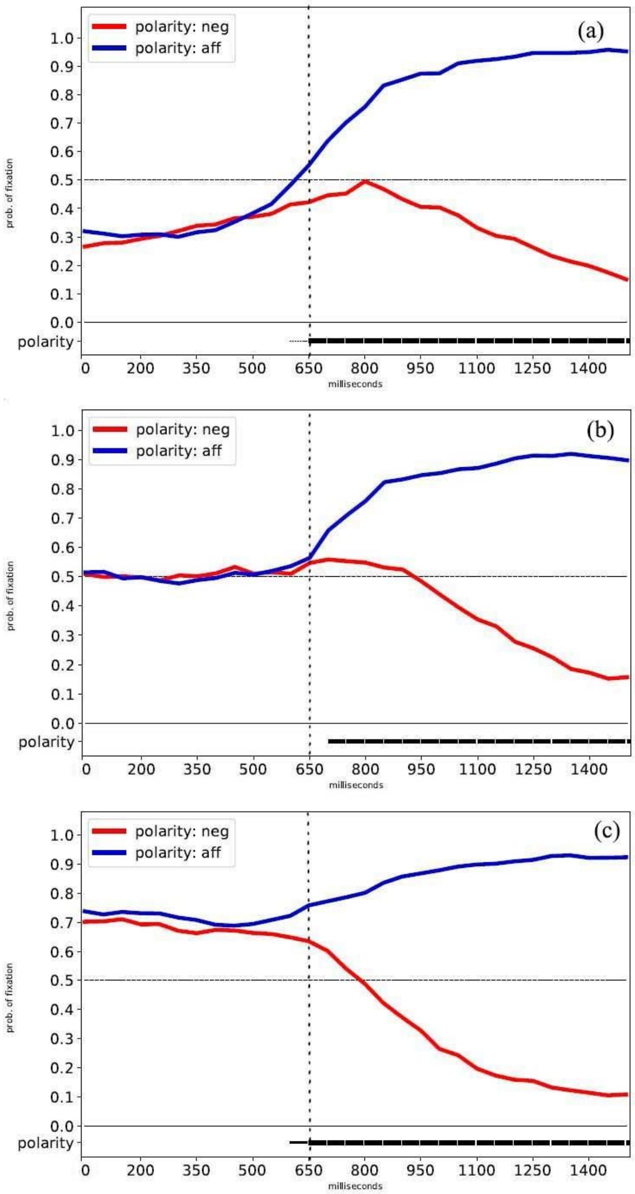


Figure 4.21. Proportion of looks to the mentioned argument (i.e., the green triangle in x) for AFF (blue) and NEG (red) sentences in conditions including one (a), two (b), and three (c) pictures of the mentioned argument. The black segments at the bottom display the significance of the main effect of *polarity*.

One mentioned argument. For the condition with one mentioned argument, graph (4.21a) shows that the blue line (AFF) and the red line (NEG) never overlap after the disambiguation offset. Quite interestingly, in both conditions we can observe an increase in fixations towards the mentioned argument. In the AFF condition, the absolute proportion of MA fixations rapidly increased above chance level (.25) after the disambiguation offset, suggesting that participants disambiguated the target picture very quickly. Instead, in the NEG condition, there was a slight increase in

MA fixations that reached 0.5 at about 800ms after the disambiguation onset. At this point, the fixations towards the mentioned argument dropped, suggesting that participants disambiguated the target also in the NEG condition. Note that the NEG condition with one mentioned argument includes three pictures of the potential targets: despite the very high base probability of target fixation (0.75), in the NEG condition participants were looking at the picture of the mentioned argument (i.e., the competitor) for about 200ms after the offset of the disambiguation. However, it should also be noted that the absolute proportion of MA fixations was higher in the AFF condition: at 800ms, it reached 0.5 in the NEG condition and 0.8 in the AFF one. In addition, a closer visual inspection of the graph reveals a different rate of MA fixations for the AFF and the NEG conditions already during the unfolding of the critical word.

Altogether, these results suggest that, in the condition with one mentioned argument, participants' visual attention was initially drawn towards the MA picture regardless of sentence polarity. This clearly indicates a delay in target identification for the NEG condition. However, target identification also occurred quite rapidly with negative sentences, as indicated by the fact that participants were looking at the mentioned argument less steadily in the NEG condition than in the AFF one even before the disambiguation offset. This finds statistical confirmation in the fact that the effect of *polarity* was revealed significant from 650ms after the disambiguation onset – nearly significant in the time-slot 600ms-650ms (see Appendix B; Table 4.16),

Two mentioned arguments. For the condition with two mentioned arguments, graph (4.21b) shows that the blue line (AFF) and the red line (NEG) never overlap after the disambiguation offset. Moreover, in contrast to what was observed in the condition with one mentioned argument (Graph 4.21a), we can see an opposite pattern of MA fixations for the two conditions from 650ms in the graph onwards. While the AFF condition was characterized by a very rapid increase in fixations towards the mentioned argument, in the NEG condition there was a constant decrease in MA fixations. A closer visual inspection of the graph reveals that participants were fixating the mentioned argument at exactly the same rate in both AFF and NEG conditions only until the disambiguation offset (650ms in the graph). Again, this indicates that the target has been quickly disambiguated in both AFF and NEG conditions, as confirmed by a highly significant effect of *polarity* from 700ms after the disambiguation onset (see Appendix B; Table 4.17).

If we compare the graphs for the conditions with one (4.21a) and two (4.21b) MA pictures, we can observe that in both conditions participants' visual attention was initially drawn towards the pictures of mentioned argument regardless of sentence polarity. However, while in the NEG condition with one MA picture participants were looking at the mentioned argument (i.e., the competitor) for about 200ms after the disambiguation offset (even if less steadily than in the AFF baseline), in the NEG condition with two MA pictures, they were faster in shifting their gaze towards the actual target of the negative sentence.

Three mentioned arguments. For the condition with three mentioned arguments, graph (4.21c) shows that the blue line (AFF) and the red line (NEG) do not overlap after the disambiguation offset. Similarly to what observed in the condition with two mentioned arguments (Graph 4.21b), we can see that the MA fixations increased in the AFF condition, but they rapidly decreased in the NEG one. Moreover, a closer visual inspection of the graph reveals that participants' looking pattern behaviour began to differ in the two conditions at about 500ms from the disambiguation onset. Before this point, the graph shows that participants were fixating the mentioned argument at exactly the same rate in both AFF and NEG conditions. Interestingly, the NEG condition with three mentioned arguments includes only one target picture: despite the very high base probability of MA fixations (0.75), in the NEG condition participants rapidly shifted their gaze towards the actual target of the verbal description already during the unfolding of the critical word. Therefore, these patterns of fixations clearly indicates that the target has been disambiguated very quickly in both AFF and NEG conditions, resulting in a significant effect of *polarity* from 600ms after the disambiguation onset – highly significant from 650ms (see Appendix B; Table 4.18).

To conclude, the comparison of the three graphs in Figure 4.21 shows a facilitating effect of the visual prominence of the mentioned argument on the interpretation process: in the NEG condition, participants were faster in shifting their gaze towards the actual target of the negative sentence as the number of pictures of the mentioned argument (i.e., the competitor) increased. Note that very similar patterns of fixations towards the mentioned argument were also reported in the descriptive analyses with cartoon characters (§4.3.3.1) and black and white geometric shapes (§4.3.3.2). However, this effect is less prominent with coloured geometric shapes: negation was processed very fast across the three experimental conditions, as indicated by the fact that participants' looking pattern behaviour in the AFF and the NEG conditions began to differ very early after the disambiguation onset. This suggests some degree of flexibility and sensitivity of negation processing to propositional and perceptual features, which will be further discussed in §4.4.4.

Summarizing, these findings provides further confirmation of the effects reported in the previous analyses on the target: first, negation displayed a significant processing penalty in target identification, compared to the affirmative baseline, as the number of potential targets increased; second, the unexpected drop in target fixations found in the NEG condition with three potential targets was due to the fact that participants' visual attention was initially drawn towards the picture of the mentioned argument (i.e., the competitor) for about 200ms after the disambiguation offset.

4.4 General discussion

In this section, we will first summarize our major findings revealed by the in-depth analyses of participants' looking pattern behaviour during the real-time comprehension of affirmative and negative sentences (§4.4.1). Then, in §4.4.2, we will discuss how these results make an important contribution to the broad theoretical debate on the processing of sentential negation outlined in chapter 2, by providing compelling evidence in favour of a non-incremental processing strategy of negation. In §4.4.3, some considerations will be made on how to reconcile our findings with those from neurolinguistic studies pointing instead to an early integration of negation into sentence meaning, and thus to an incremental processing. Finally, in §4.4.4, we will discuss how the complexity of visual and linguistic information can affect the construction of the negative meaning, on the basis of some differences and some common features that emerged from participants' looking pattern behaviour across item types.

4.4.1. Our results: preliminary considerations

The eye movement analyses conducted on the target revealed two main processing features underlying sentence interpretation. First, we found that participants were systematically slower in target identification when presented with negative sentences than with the corresponding affirmative ones, as indicated by a lower target preference in the three negative conditions compared to the affirmative baseline. Second, this processing penalty conveyed by negation increased as the number of target pictures displayed in the visual scenario increased. This latter finding is quite surprising and, to some extent, also counterintuitive, if we consider that an increase in the number of target pictures corresponds to a higher base probability of target fixations. Given the four areas of interest in which the visual scenario was divided (§4.1), participants had a 25% of probability of being already looking at the target picture before the onset of the critical word (i.e., the disambiguation point) in the condition with only one target picture: this base probability increased to 50% and 75% in the conditions with two and three target pictures, respectively. Nonetheless, the analysis of participants' looking pattern behaviour showed that, as the number of potential target increased, participants were looking at the potential targets less steadily in the negative condition than in the affirmative baseline, as revealed by a larger difference in target preference between the two polarity conditions at the increase in the number of target pictures. For the aim of the present discussion, it is worth noting that, in the negative condition, an increase in the number of potential targets corresponded to a decrease in the number of pictures of the mentioned argument. While in the affirmative condition the pictures of the mentioned argument were the visual referents of the verbal description, in the negative ones they were instead the pictures to avoid, as they represented the negated information. In other words, the pattern of findings described above reveals that, in the negative condition, participants were faster in target identification when more pictures of the mentioned argument (i.e., more visual competitors) were displayed in the visual scene. The visual prominence of the mentioned argument had, therefore, a facilitating effect on the processing of negative sentences, resulting in a reduced penalty for target identification, compared to the affirmative baseline, as the number of pictures of the mentioned argument increased.

Nonetheless, the eye movement data also revealed that the processing costs for negative sentences could not be completely eliminated: even if the target identification with negative sentences was certainly enhanced by the visual prominence of the mentioned argument, participants were still slower in shifting their attention towards the target than in the affirmative baseline, as indicated by a lower target preference in all the three negative conditions. Remarkably, negative sentences displayed higher processing costs despite an adequate pragmatic context for the use of negation was provided. In our experimental design, both the negated and the actual state of affairs were always represented in the visual scene: negative sentences were therefore used to deny the presence of an entity (i.e., the negated situation) which was relevant in the discourse context (Wason 1959, 1961; Givòn 1978, Horn 1989). Moreover, unlike in Orenes et al. (2014), the reference resolution task was consistent across experimental conditions: although the visual scene could include more pictures of the potential target, the introduction of a subordinate/coordinate clause always allowed participants to eventually identify a univocal referent for the verbal description. Therefore, the use of negation was fully informative in this discourse context, as it allowed the listeners to infer some relevant information about which was the figure under discussion by expressing a deviation from an expectation established by the visual scene. This allows us to argue that **the higher processing costs reported for negative sentences compared to the affirmative baseline cannot be attributable to an unsupportive context of utterance,** as assumed by pragmatic accounts of negation processing (among others, Nieuwland and Kuperberg 2008, Dale & Duran 2011, see §2.2.2).

The analysis conducted on the mentioned argument provided further confirmation of the higher processing costs reported for negative sentences compared to the affirmative baseline. Strikingly, the analysis of participants' looking pattern behaviour revealed that this processing penalty was attributable to an initial pattern of fixations towards the picture(s) of the mentioned argument after the onset of the critical word: this indicates a delay in target identification for the negative condition, as the picture of the mentioned argument corresponded to the visual representation of the negated rather than the actual state of affairs described in the sentence. Negation seems therefore to be integrated at a later moment into sentence meaning, as the listeners actively exploit the visual representation of the mentioned argument during the early moments of sentence comprehension. In the descriptive analyses on the target, we reported an initial decrease in target fixations for the negative condition with three potential targets immediately after the disambiguation offset, which was more robust with coloured (§4.3.2.3) and black and white geometric shapes (§4.3.2.2) but clearly distinguishable also with cartoon characters (§4.3.2.1). This looking pattern behaviour is quite unexpected if we consider the very high base probability of target fixation in this experimental condition: importantly, the descriptive analysis on the mentioned argument revealed that this initial decrease in target fixations was due to the fact that participants were looking at the only picture of the mentioned argument displayed in the visual scene at exactly the same rate as in the affirmative baseline. Quite interestingly, we also found that participants were faster in shifting their gaze towards the actual target of the negative sentence as the number of pictures of the mentioned argument increased. The fact that negation was integrated faster into sentence meaning when more pictures of the mentioned argument were displayed in the visual scene provides further confirmation that **the visual prominence of the negated information has a facilitating effect on the processing of negative sentences.**

To sum up, the eye movement data provided compelling evidence that negative sentences always displayed higher processing costs than the corresponding affirmatives. The visual prominence of the mentioned argument (i.e., the negated information) has been found to have a facilitating effect on negation processing: however, the processing penalty conveyed by negation could not be completely eliminated, despite an adequate pragmatic context of utterance was provided. Significantly, this processing penalty is attributable to an initial pattern of fixations towards the picture(s) of the mentioned argument reported in all the negative conditions. This evidence speaks in favour of a later integration of negation into sentence meaning, which, however, occurred faster when the mentioned argument was perceptually more prominent in the visual scene. Our data support the view that **the negated information is actively exploited by the parser during real-time sentence comprehension**, resulting in a facilitating effect on the interpretation process of the negative sentence.

4.4.2 Towards a non-incremental view of negation processing: evidence in favour of the Two-Step Simulation Hypothesis

The positive effect of the visual prominence of the mentioned argument reveals that it was the activation and the retrieval of the negated information to hinder the processing cost of the negative sentences compared to that of the corresponding affirmatives. This evidence is strongly in compliance with a **non-incremental processing strategy of negation** (§2.2.1), which maintains that the negated information must necessarily be activated during the comprehension process of negative sentences. According to the Two-Step Simulation Hypothesis (Kaup et al. 2007, see §2.2.1.3), the processing of negative sentences consists of two temporarily distinct and subsequent stages, which correspond to the construction of two different simulations of the negated and the actual state of affairs, respectively. In this view, negation is not immediately integrated into sentence meaning, as the interpretation of the negative statement necessarily requires the former evaluation of its positive counterpart. The higher processing costs traditionally reported for negative sentences compared to the corresponding affirmatives would hence be determined by the need to construct and compare two different mental simulations. Crucially, a number of studies has reported a facilitating effect on the computation when negative sentences are presented in a supportive pragmatic context: during the early stages of the processing, the comprehenders can benefit from being presented with a picture representing the negated state of affairs, as they can retrieve the mental simulation under construction directly from the discourse situation instead of creating it *ex novo*. Evidence in this directions comes from more classical experimental paradigms of language comprehension (Carpenter & Just 1975; Kaup et al. 2005, 2006, 2007, 2007b; Lüdtke & Kaup 2006; Vender & Delfitto 2010; Hasson & Glucksberg 2006), EEG-ERPs studies (Fischler et al. 1983; Lüdtke et al. 2008, Scappini et al. 2015), as well as from studies on negation processing conducted within Visual World Paradigm (Orenes et al. 2014, 2015). The facilitating effect of the visual prominence of the mentioned argument on the interpretation process can be explained accordingly: having more pictures representing the negated situation in the visual scene reduced the processing penalty of negative sentences, as it made the retrieval and the activation of the first mental representation required in the processing much easier for the parser.

Strikingly, incremental models of negation processing (§2.2.2) cannot explain the reported facilitating effect of the negated information: quite the opposite, they predicted an increased penalty for target identification compared to the affirmative baseline at the increase in the number of pictures of the mentioned argument (§4.2.4). Incremental accounts maintain, in fact, that the processing of negative sentences resembles that of the corresponding affirmative, with no need to necessarily represent the positive counterpart to access the semantic meaning of the sentence. In this view, the higher processing costs traditionally reported for negative sentences are entirely attributable to an inadequate context of utterance, which requires the parser to adjust the lacking contextual information, and consequently slows down the comprehension process. When a pragmatically felicitous context is provided, as in the case of our experiment, the processing of negative sentences would not be more demanding than that of the corresponding affirmative sentence (Wason 1965; De Villiers & Flusberg 1975; Glenberg & Robertson 1999; Dale & Duran 2011; Nieuwland & Kuperberg 2008; Staab et al. 2008, see §2.2.2.1). It follows that, if the activation of the mentioned argument is not required for the interpretation process of negative sentences, having more pictures representing the negated situation in the visual scene would have hindered rather than facilitated the comprehension process. These pictures, activated merely as a consequence of the lexical interference and the visual reference resolution process, were not supposed to be actively exploited by the parser during real-time sentence comprehension, and they would have been more difficult to inhibit due to their visual prominence.

Despite the fact that the visual prominence of the mentioned argument has reduced the delay in target identification for negative sentences compared to the affirmative baseline, we found that the processing penalty displayed by negation could not be completely eliminated. The analyses of participants' looking pattern behaviour revealed, in fact, that participants were always slower in target identification when presented with negative sentences than with the corresponding affirmative ones, even in the one that turned out to be the easiest experimental condition (i.e., three pictures of the mentioned argument). Again, incremental models cannot account for this piece of experimental evidence since they maintain that the processing of negative sentences does not require extra processing time nor effort in comparison with that of affirmatives when an adequate pragmatic context is provided (§2.2.2.1). Crucially, the Two-Step Simulation Hypothesis (Kaup et al. 2007) explains (and also predicts) this persisting penalty conveyed by negation by assuming that the processing of negative sentences is inherently more demanding than that of the corresponding affirmatives as it involves more complex and partially different cognitive representations (§2.2.1.3). Compared to that of affirmatives, the comprehension process of negative sentences requires in fact the construction and the subsequent evaluation of one more mental simulation, corresponding to the negated state of affairs. If the visual prominence of the mentioned argument can make the retrieval and the activation of this negated information easier for the parser, negation processing is expected to be nevertheless more demanding than that of affirmatives due to the additional processing step involved in the computation.

As discussed above, the analysis on the mentioned argument provided compelling evidence of a later integration of negation into sentence meaning, as shown by an initial pattern of fixations towards the picture(s) of the mentioned argument in all the negative conditions. Nonetheless, the comparison of the listeners' looking pattern behaviour between affirmative and corresponding negative sentences across visual scenes containing a variable number of pictures of the mentioned argument demonstrated that negation was integrated faster into sentence meaning when more pictures of the mentioned argument were depicted in the visual scene, with participants being faster in shifting their gaze towards the actual target of the negative sentence. Significantly, the Two-Step Simulation Hypothesis (Kaup et al. 2007) predicts an initial insensitivity to negation during the earliest moments of sentence comprehension, due to the retrieval/construction of the simulation of the positive state of affairs occurring at this stage in the processing. In a non-incremental view of negation processing, the late inhibition of the negated meaning is interpreted as evidence of the second stage of sentence comprehension, during which the simulation of the positive state of affairs is rejected and negation is eventually integrated into sentence meaning. Evidence of a different sensitivity to negation between early and late stages of sentence processing has been attested in both behavioural (Hasson & Glucksberg 2006, Kaup et al. 2007, 2005, 2006) and EEG-ERPs studies (Fischler et al. 1983; Lüdtke et al. 2008), showing that, during the earliest moments of the processing, the comprehender can benefit from being presented with a picture representing the negated situation, which corresponds to the mental simulation under construction.

For the aim of the present discussion, it should be noted that a number of studies assuming an incremental strategy of negation processing have also provided evidence in favour of a late inhibition of the negated information (§2.2.2.2). Nonetheless, these studies maintain that the suppression of the information occurring under the scope of negation is strongly influenced by contextual considerations: when the negated information is not useful for sentence interpretation, its accessibility is considerably reduced from the earliest moments of sentence comprehension; instead, when the negated information is relevant for discourse coherence purposes and for the interpretation process, it is initially retained and receives a weaker interpretation resembling the original positive concept (Giora et al. 2004, 2005, 2007; Giora 2006; Paradis and Willners 2006). In this view, the possible retainment of the negated information is primarily affected by contextual and pragmatic factors. These considerations are in line with what assumed by pragmatic accounts of negation: the processing of negative sentences may undergo a two-stage based interpretation in pragmatic unsupportive contexts, where the comprehension process in slowed down by participants' need to adjust the lacking contextual information (among others Nieuwland and Kuperberg 2008, Dale & Duran 2011, but see also Orenes et al. 2015 in §3.3.1). Nevertheless, throughout the discussion, we have seen that incremental models of negation processing cannot account for the systematic processing penalty displayed by negation in a supportive context of utterance nor for the facilitating effect of the visual prominence of the negated information on the processing. In contrast, these two main findings strongly suggest that the processing of negative sentences involves more complex and partially different cognitive representations compared to that of affirmatives, as proposed by the Two-Step Simulation Hypothesis (Kaup et al. 2007). For this reason, we interpret the initial insensitivity to negation revealed by the eye movement analysis on the mentioned argument as evidence of a non-incremental processing strategy of negation, rather than as a consequence of contextual and pragmatic factors.

Importantly, the manipulation of the visual prominence of the mentioned argument allowed us to provide a clear interpretation of these language-mediated eye movements by overcoming those methodological limitations discussed for previous visual world studies on negation processing (Orenes et al. 2014, 2015, see §3.3), related to possible visual biases due to effects of lexical activation (Cooper, 1974; Tanenhaus et al. 1995; Allopenna et al. 1998; Huettig & Altmann 2005) and reference resolution (§3.4). The initial pattern of fixations towards the mentioned argument reported across negative conditions corresponds to an actual stage of the comprehension process of negative sentences: during the early moments of sentence comprehension, the visual representation of the negated information was actively exploited by the parser for the retrieval and subsequent activation of the mental simulation of the negated state of affairs, resulting in a facilitating effect on the real-time interpretation process. As discussed in chapter 3, language-mediated eye movements do not simply reflect the integration of linguistic information from the spoken sentence with perceptual information retrieved by the visual context: crucially, they also reflect the real-time mapping of the linguistic input onto dynamically updated and context-determined mental representations (Cooper 1974; Tanenhaus et al. 1995; Allopenna et al. 1998; Dahan & Tanenhaus 2005; Altmann & Kamide 2009, see §3.2.3.2 for a detailed discussion). The deviation of the eye gaze pattern in the negative condition from that in the affirmative one indicates the exact moment in which negation affected sentence meaning: at this later stage of the interpretation process, the mental simulation of the positive state of affairs was rejected and replaced with a simulation corresponding to the actual negative meaning of the sentence.

Taken together, our findings are strongly in compliance with a non-incremental view of negation processing, along the lines of the Two-Step Simulation Hypothesis (Kaup et al. 2007). First, we provided compelling evidence that the processing of negative sentences is inherently more demanding than that of the corresponding affirmatives also when an adequate pragmatic context of utterance is provided. Second, we reported a facilitating effect of the visual prominence of the negated information on processing, suggesting that the comprehender actively exploits the visual representation of the mentioned argument during the early moments of real-time sentence comprehension. This found further confirmation in the initial pattern of fixations towards the mentioned argument reported in all negative conditions, which provided compelling evidence of a late integration of negation into sentence meaning. The higher processing costs traditionally reported for negative sentences, and replicated in the current study, are therefore attributable to the fact that the processing of negative sentences always involves first the retrieval/construction of one more mental simulation (i.e., the negated state of affairs) compared to that of the corresponding affirmatives.

4.4.3 On how to reconcile our findings with the preliminary results from Embodiment Cognition Research on negation processing

Evidence of a late integration of negation into sentence meaning openly goes against the neurolinguistic findings on the processing of sentential negation discussed in chapter 2. Embodiment cognition research (§2.2.2.2) has provided, in fact, substantial neurobiological evidence that the processing of negative sentences induces a very early inhibition of those motor areas which are usually activated by the computation of the corresponding affirmatives (Tettamanti et al. 2008; Tomasino et al. 2010; Liuzza et al. 2011; Alemanno et al. 2012; Bartoli et al. 2013; Foroni and Semin 2013, Papeo et al. 2012). This early suppressive effect, which occurs already within 500ms after stimuli onset, speaks in favour of an incremental strategy of negation processing, as the suppression of the negated information occurs as soon as semantic effects are observable in the brain. As already pointed out, this neurolinguistic evidence poses a significant problem for the Two-Step Simulation Hypothesis, which considers the mental representations involved in language comprehension to be experiential in nature, featuring the activation of those motor brain areas deputed to non-linguistic cognitive processes such as perception and action (Zwaan & Radvansky 1998; Pulvermüller et al. 2001; Pulvermüller 2002; Zwaan & Taylor 2006; Zwaan 2004; Kaup et al. 2007, see §2.2.1.3). Hence the question: if embodiment cognition research has provided evidence for a very early inhibition of the negated information, how is it possible that the activation of the very same information does significantly affect the processing costs of negative sentences?

Although these findings seem in all respects quite contradictory, some important considerations must be made. The attentive reader will not have failed to notice that we had already underlined significant limitations of the neurolinguistic studies on negation processing reported in literature (§2.2.2.2). So far, embodiment cognition research has in fact investigated only limited aspects of negation processing through passive listening tasks, by focusing on simple and short declarative sentences presented without any linguistic or more general discourse context. Moreover, these studies have employed only a limited set of hand-action related verbs in first singular person. Quite intuitively, this neuro-imaging evidence appears hardly comparable with the findings from our experimental study, in which we investigated more complex linguistic structures, denoting performed actions, perceptual properties or existential properties of the described entities, as well as the role of contextual visual cues in the interpretation process (§4.2.2).

If neurolinguistic research on action-related verbs has provided convincing evidence that the construction of the negative meaning blocks the access to some neural information related to the positive counterpart, very little is known about the effect of negation on those semantic contents that could involve modality-specific systems other than the sensory-motor one (e.g., perceptual cues) or more abstract features of meanings (Papeo et al. 2012). Therefore, in our opinion, neurolinguistic research cannot be taken as evidence against findings from studies investigating more complex and context-related aspects of the interpretation process, that point to a non-incremental strategy of negation processing. In this respect, Bartoli et al. (2013) have suggested that, when the comprehender is required to express metalinguistic judgment about the truthfulness of the experimental sentences, it might be necessary for her to simulate both the negated and the actual state of affairs. For this reason, they do not exclude the possibility that, during the evaluation process, the deactivation of motor brain areas might be preceded by an initial stage of motor activation. The same explanation could hold for the execution of a reference resolution task, although further research is definitely needed to fully understand the involvement of different brain areas in the processing of heterogeneous negative structures presented within different contexts of utterance.

To conclude, it is worth noting that some scholars have provided alternative explanations for the role of sensori-motor systems in language processing (§2.2.2.1). For instance, Patterson et al. (2007) assumed that the activation of motor brain areas during language processing would be determined by a spreading activation from other neuronal regions where the representations underlying language comprehension occur. In this view, semantic representations are completely independent from sensori-motor information: the activation of motor brain areas would occur only when motor features related to word meaning are required by the context, as in the case of action-related verbs. Similar considerations have been made by Mahon and Caramazza (2008), who argue that the activation of motor brain areas simply integrates more abstract representations underlying sentence comprehension. Assuming one of these theoretical perspectives might reconcile the neurolinguistic evidence and the findings from other experimental methodologies: however, since the current study did not involve the use of neuro-imaging techniques, at the moment this remains a speculative explanation, which is not of primary interest for the aim of the present discussion.

4.4.4 Sensitivity to propositional and perceptual features: some considerations from the differences emerged with coloured geometric shapes

In this experiment, we included three different types of visual and linguistic stimuli: cartoon characters with declarative sentences denoting performed actions and events (e.g., *Aladdin is/is not pitching a tent*), coloured geometric shapes with declarative sentences describing perceptual properties (e.g., *the circle is/is not red*), and black and white geometric shapes with declarative sentences expressing existential properties of the described entities (e.g., *there is/is not a square*). The aim of this manipulation was to investigate whether the complexity of the visual and linguistic information might affect the online construction of the negative meaning, and, if so, to what extent.

The eye movement analyses showed a very similar pattern of fixations across item types, revealing two main common processing features underlying the interpretation of negative sentences, summarized as follows: i) a systematic penalty in target identification for negative sentences compared to the corresponding affirmative ones; and ii) a facilitating effect of the visual prominence of the negated information, which reduced, but could not eliminate, the aforementioned penalty displayed by negation. Interestingly, we found that these effects were less robust with coloured geometric shapes than with the other item types. As a matter of fact, the descriptive analysis on the mentioned argument revealed that participants' looking pattern behaviour in the affirmative and corresponding negative conditions began to differ very early after the disambiguation onset, regardless of the number of pictures of the mentioned argument displayed in the visual scene. This early deviation of the eye gaze pattern indicates that negation was quickly integrated into sentence meaning in all the three negative conditions. Furthermore, the statistical analyses on the target showed that, in our area of interest[85], the proportion of looks to the target was always higher than .60 for all the negative conditions (.69,.63,.64). In contrast, in the same broad time-window, the target preference in negative conditions ranged between .43 and .55 (.43,.49,.55) for cartoon characters, and between .28 and .52 (.28,.39,.52) for black and white geometric shapes, respectively. In addition, the positive effect of the visual prominence of the mentioned argument was less robust with coloured geometric shapes than with the other item types, as evidenced by a constant processing penalty conveyed by negation in the conditions with two and three potential targets.

Therefore, this pattern of results indicates that, with coloured geometric shapes, the target picture was disambiguated very quickly across negative conditions and, accordingly, that negative sentences were processed faster than with black and white geometric shapes and cartoon characters. This is particularly evident if we compare the participants' looking pattern behaviour in the condition with one mentioned argument across the three item types. The eye movement analyses showed that this condition displayed the higher processing costs for negative sentences in comparison to the affirmative baseline: strikingly, this was due to the fact that, after the disambiguation offset, participants were looking at the picture of the mentioned argument longer and more steadily than in the conditions with two and three mentioned arguments before shifting their gaze towards the actual target of the negative sentence. For cartoon characters (§4.3.2.1) and black and white geometric shapes (§4.3.2.2), the descriptive analyses revealed that, after the disambiguation offset, participants focused on the picture of the mentioned

[85] We identified as major area of interest the one-second time-window from the offset of the critical word (650ms) to the onset of the subordinate/coordinate clause (1650ms).

argument for 300ms and 350ms, respectively. Instead, for coloured geometric shapes (§4.3.2.3), the analysis clearly showed a different rate of fixations towards the mentioned argument between the affirmative and corresponding negative condition already during the unfolding of the critical word, with the two lines departing at about 150ms before the disambiguation offset.

Taken together, these findings reveal that the processing of sentential negation displays some degree of flexibility and sensitivity to propositional and perceptual features. Colour is a perceptual property which is widely acknowledged in literature as one of the guiding attributes of the visual attention that aids target identification in the surrounding environment (Wolfe & Horowitz 2004; Jost et al. 2005; Snowden 2002, Kim 2010, among others). As regards language processing, a number of visual world studies[86] has shown that the listeners make active use of the perceptual attributes of the depicted objects such as colour during the real-time integration of the visual and linguistic input (Huettig et al. 2011; Huettig & Altmann 2004, 2007; Dahan & Tanenhaus 2005, Yee et al. 2009). Based on these considerations, we hypothesize that negation was processed faster with coloured geometric shapes because the linguistic input denoted surface properties of the described entities which were perceptually very salient. This made the retrieval of the perceptual information from the visual scene much easier: as a consequence, listeners have been faster in activating, and subsequently inhibiting, the mental representation of the negated colour information during the interpretation process, and the positive effect of its visual prominence was minimal. Note that a facilitating effect on processing was also found for affirmative sentences in comparison to the other item types. Furthermore, from a propositional perspective, it is worth noting for the present discussion that the interpretation of colour adjectives is widely agreed to be easier than that of other types of adjectives, and to require minimal processing difficulties (Sedivy et al. 1999, Sedivy 2003, 2005; Aparicio et al. 2015, among others). Based on Kamp and Partee's (1995) classification, colour belongs to the class of the so-called *intersective adjectives*, which can be easily interpreted independently from the context of utterance as they have a more stable core meaning. For instance, if described as a *green triangle*, the referred triangle can be interpreted as being green or not, without taking into consideration other geometric shapes or other green objects in the context (vs. the interpretation of e.g., *tall*, which requires a comparison between two entities). Based on these observations, we assume that the simple propositional decoding of the colour adjective, together with the easier retrieval of the perceptual information had a facilitating effect on the real-time integration of the visual and linguistic information with coloured geometric shape items.

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[86] The interested reader might to §3.2.3.1 for a detailed discussion on how perceptual properties of the visual objects can determine shifts in the listener's overt visual attention.

In contrast, the item conditions with cartoon characters and black and white geometric shapes required a deeper evaluation: the former described different characters performing complex actions on/with common objects, whereas the latter involved more abstract features of meaning, such as the presence or the absence of geometric shapes. Intuitively, the encoding of such linguistic information is more complex than that required for perceptual features such as colours, also with regard to the mental representations involved in the comprehension process. And, in fact, we found that the visual prominence of the mentioned argument had a greater facilitating effect on the processing of negative sentences with these two item types, suggesting that participants did importantly benefit from being presented with more pictures representing the mental simulation under construction (i.e., the negated situation). In particular, the item condition with black and white geometric shapes is asymmetrical with respect to the others. On one hand, the visual stimuli associated with both cartoon characters and coloured geometric shapes always contained a representation of the sentence subject (e.g. Aladdin is found in all the four quadrants as well as the coloured triangles). On the other, instead, with black and white geometric shapes participants had to identify whether a specific object existed or not in the visual context. This is arguably the reason why we found that black and white geometric shape items were more difficult than the coloured ones, despite both these item types involved the same kind of objects (i.e., geometric shapes): in the latter, the relevant object was always represented – even with a different surface colour (e.g. yellow triangle instead of a green one); in the former, instead, either you had the relevant shape (e.g., triangle) or you had a completely different one (e.g., circle).

Summarizing, the comparison of participants' looking pattern behaviour across item types revealed that the processing of sentential negation is affected by the complexity of the visual and linguistic information. Colour had a facilitating effect on the interpretation process, arguably due to its perceptual saliency and its simpler propositional content. Conversely, negation was processed slower with cartoon characters and black and white geometric shapes, as the greater linguistic and visual complexity of the presented stimuli made the comprehension process more demanding. Interestingly, these last two item conditions were also those that benefited the most from the visual prominence of the negated information, which made the computation of the negative meaning significantly easier.

To conclude, one final remark regarding the cognitive mechanisms underlying the processing of sentential negation. On the one hand, we found that negation processing is sensitive to propositional and perceptual features of the presented stimuli, which has a facilitating effect on the negative sentence interpretation. On the other hand, the same looking pattern behaviour was reported across the three item conditions, indicating that participants adopted the same processing strategy during the real-time interpretation of negative sentences. This robust evidence of a common cognitive strategy underlying negation processing is at odds with previous findings showing that the integration of negation into sentence meaning is affected by the types of predicates and terms involved (Mayo et al. 2014, see §2.2.2.2). In particular, Orenes et al. (2014) assumed that there are two ways of processing negation depending on the verbal context provided: either by simulating the alternative affirmative or by applying a symbolic tag to the negated information when this alternative affirmative is not available. These different processing strategies would be responsible for the different pattern of fixations reported for negative sentences in the binary and the *multary* verbal contexts in comparison to the affirmative baseline. As thoroughly discussed in §3.3.2, these different patterns of fixations might not necessarily imply two different processing strategies: rather, they can be considered the consequence of an inadequate context of utterance in the *multary* condition. Nonetheless, despite the underlined limitations of Orenes et al. (2014), which have biased, in our opinion, participants' looking pattern behaviour in the negative condition, it is worth noting that our findings revealed a coherent pattern of fixations across item types, with participants initially focusing on the negated information and then shifting their visual attention towards the actual target of the negative sentence.

4.5 Concluding remarks

The aim of the present study was to investigate two core and widely-debated aspects of negation processing: the role of the argument of negation (i.e., the negated information) in the interpretation process, and the timing and the mode of negation integration into sentence meaning. In order to so do, we conducted an *identification task with eye recording* to compare the time course of sentence comprehension during the processing of affirmative and corresponding negative sentences. Unlike in previous studies on negation processing conducted within the visual world paradigm (§3.3), we included a metalinguistic feedback to assess the final sentence comprehension, and we manipulated the visual prominence of the negated information by varying the number of pictures of the mentioned argument from one to three (§4.1). This manipulation allowed us to answer our two main research questions by controlling at the same time possible visual biases related to lexical and the reference resolution process:

i) what is the role of the argument of negation in the interpretation process?

The analysis of the participants' looking pattern behaviour revealed an initial pattern of fixations towards the picture(s) of the mentioned argument after the onset of the critical word in all the three negative conditions. During the early moments of the real-time comprehension process, the visual representation of the negated information was actively exploited by the listener for the retrieval and subsequent activation of the mental simulation of the negated situation. In addition, the more the pictures of the mentioned argument (i.e., visual competitors) displayed in the visual scene, the faster participants were in shifting their gaze towards the actual target of the negative sentences, as confirmed by a reduced processing penalty for target identification compared to the corresponding affirmative baseline. The visual prominence of the argument of negation had a positive effect on the processing costs of negative sentences, which are hindered by the retrieval and the activation of the negated information.

ii) how quickly is negation integrated into sentence meaning?

The comparison of participants' looking pattern behaviour during the real-time interpretation of affirmative and corresponding negative sentences revealed that negation was integrated at a later moment into sentence meaning, as evidenced by the aforementioned initial pattern of fixations towards the mentioned argument across negative conditions. This indicates a delay in target identification for negative sentences, as the picture of the mentioned argument corresponded to the visual representation of the negated rather than the actual situation described in the sentence. Compared to the affirmative baseline, participants were always slower in target identification across negative conditions. As mentioned, the visual prominence of the negated information had a facilitating effect on negation processing: participants were in fact faster in shifting their gaze towards the actual target of the negative sentence as the number of pictures of the mentioned argument increased. However, although negation was integrated faster into sentence meaning, its processing penalty for target identification compared to the affirmative baseline could not be completely eliminated.

Summarizing, our results provided compelling evidence that the processing of negative sentences is inherently more demanding than that of the corresponding affirmatives. Moreover, the visual prominence of the negated information has a positive effect on the interpretation, as it reduces, but does not cancel, the processing penalty conveyed by negation for target identification compared to the affirmative baseline. Finally, negation is integrated at a later moment into the semantic meaning of the sentence since, during the early moments of sentence comprehension, the comprehender actively exploits the visual representation of the negated information.

Taken together, these findings strongly support a non-incremental processing strategy of negation, following the Two-Step Simulation Hypothesis (Kaup et al. 2007). In this view, negation is not immediately integrated into sentence meaning, as the comprehension of a negative statement always undergoes a preliminary evaluation of its positive counterpart. This additional computational step determines the higher processing costs reported for negative sentences compared to the corresponding affirmatives. Crucially, comprehenders can benefit from being presented with a visual scene depicting the negated situation during the early stages of the processing, as they can directly retrieve the mental simulation under construction from the discourse context rather than creating it *ex novo*. However, although a supportive pragmatic context can have a facilitating effect on the computation, the higher processing costs reported for negative sentences cannot be completely eliminated, due to the nature of the mental simulations involved in the comprehension process.

To conclude, the comparison of participants' looking pattern behaviour across our three item conditions (cartoon characters, black and white, and coloured geometric shapes) revealed that the processing of sentential negation is sensitive to perceptual and propositional features of the visual and linguistic information provided. In fact, when the negated information is perceptually more salient or easier to encode, as in the case of coloured geometric shapes, negation is integrated faster into sentence meaning. Nonetheless, the eye movement analyses showed very similar pattern of fixations across item types, providing compelling evidence for a common cognitive strategy underlying negation processing, which is non-incremental in nature.

5 The processing of sentential negation in atypical populations: the case of developmental dyslexia

The second part of the present work is dedicated to the processing of sentential negation in individuals diagnosed with developmental dyslexia. While researchers have extensively studied the processing of sentential negation in typical populations (§2), only a few and quite recent studies have been conducted to investigate negation processing in children and adults with developmental dyslexia. In this chapter we will outline the theoretical framework of our follow-up study in chapter 6, that aims at disentangling the relationship between developmental dyslexia, working memory and negative sentence processing.

In the first section of this chapter (§5.1), we will provide a brief overview of developmental dyslexia and discuss its major linguistic manifestations. Despite the well-known reading and spelling difficulties that characterize this disorder, dyslexics suffer from important phonological and phonology-related deficits, as well as from an impaired grammatical competence. Significantly, throughout the discussion we will see how dyslexics manifest remarkable difficulties in the computation of complex linguistic operations, which are particularly demanding in terms of processing resources. In §5.2, after introducing the most influential model of working memory, we will discuss the experimental evidence pointing to a significant correlation between working memory deficits and the wide range of linguistic (and attentional) impairments that characterize developmental dyslexia. Finally, we will introduce the *Working Memory Deficit Hypothesis* (McLoughlin et al. 1994, 2002), which provides an exhaustive explanation for all the deficits attested in dyslexia by assuming specific limitations in dyslexics' working memory capacity and processing resources. In the third section of this chapter (§5.3), we will review the little experimental literature that has so far explored the relationship between working memory resources, developmental dyslexia and negative sentence comprehension. Throughout the discussion, we will underline some important limitations of these studies, which are intrinsically related to the behavioural nature of the experimental paradigm employed to investigate sentence comprehension. Furthermore, we will also see how these works have provided conflicting evidence on whether negation represents a specific source of processing difficulties for dyslexics. Based on these considerations, as well as on our previous findings on the processing of sentential negation in typically developed adults, in §5.4 we will outline the main research questions of our follow-up study in chapter 6.

5.1 Developmental dyslexia: an overview

Developmental dyslexia is a specific learning-based disability that interferes in particular with the acquisition of language. Despite an adequate intellectual ability and literacy exposure, individuals with developmental dyslexia have remarkable difficulties in properly acquiring reading and spelling skills: in particular, dyslexics perform very poorly in the reading and spelling of irregular words and non-words, displaying an overall difficulty in decoding letter-sound associations compared to age-matched normal readers.

According to the International Dyslexia Association, this disorder affects 5-15% of the population, which equates to around 700 million people worldwide (IDA 2017). In addition, a different distribution of the phenomenon has been reported across countries: for instance, while in Italy developmental dyslexia affects 3-4% of the population, the percentage increases up to 15-20% in the United States. However, this cross-linguistic discrepancy does not necessarily imply a greater diffusion of developmental dyslexia among English speakers: rather, it simply indicates a wider manifestation of reading and spelling difficulties in languages with an opaque orthographic system, such as English, characterized by less reliable phoneme-grapheme correspondence rules. Consider, for instance, the different possible pronunciations (in bold) of the diphthong *ou* in the English words *though* [ð**oʊ**], *tough* [t**ʌ**f], and *through* [θr**u**]. Conversely, the mapping between graphemes and phonemes is more regular in languages such as Italian: for instance, the consonant cluster *ch* is always pronounced [*k*], regardless of its position within the word and of the following vowel sound. Italian speakers have hence more chances to read properly both regular (e.g., *chiesa* [ˈ**k**jɛza] - *church*) and irregular words (e.g., *pachiderma* [pa**k**iˈdɛrma] - *pachyderm*), being facilitated by a more transparent orthographic system. Based on these considerations, the different percentages concerning the distribution of developmental dyslexia must therefore be interpreted with caution, as they are likely to be underestimated: reading and spelling difficulties are easier to detect in languages allowing more than one possible letter-sound association, whereas they might go unnoticed in more transparent languages.

A large number of functional imaging studies have confirmed the neurobiological basis of developmental dyslexia[87]. Individuals with dyslexia are in fact characterized by both anatomical and functional abnormalities in the left hemisphere language network, such as consistent under-activations in left temporoparietal and occipitotemporal regions (Dèmonet et al. 2004, Shaywitz & Shaywitz 2005, Paulesu et al. 2001): the former is involved in phonological processing and phoneme-grapheme conversion, while the latter plays a crucial role

[87] The interested reader might refer to Peterson & Pennington (2012) for a comprehensive review of the neurobiological bases of developmental dyslexia.

in processes of word recognition. Abnormal activations of the left interior frontal gyrus are also commonly reported, together with local white matter changes in this brain area as well as in the left temporoparietal regions (Nagy et al. 2004, Niogi & McCandliss 2006, Klingberg et al. 2000). In addition, it has been demonstrated that developmental dyslexia is a highly inheritable disorder: a child has a 50% chance of being dyslexic if they have a parent or a sibling who is in turn dyslexic (Gayan & Olson 1999, Galaburda et al. 2006, Kaminen & Hannula-Jouppi 2003).

Furthermore, it is worth noting that individuals with a diagnosis of dyslexia often present other developmental impairments: in particular, the co-occurrence of dyslexia with *dysorthographia* (i.e., difficulty in acquiring, recognizing and reproducing orthographic coding) and *dysgraphia* (i.e., impaired handwriting) are very common. Significantly, in a study on 300 Italian dyslexic children, Gagliano and colleagues (2007) reported an overlapping probability of 98,7% between dyslexia and *dysorthographia*, and of 82,7% between dyslexia and *dysgraphia*, respectively. Also worth mentioning is a subsequent study by Stella and colleagues (2009), who reported lower levels of comorbidity between dyslexia and *dysorthographia* (65,2%), *dysgraphia* (43,5%). Other disorders that may accompany developmental dyslexia are known as *dyscalculia* (i.e., difficulty in learning or comprehending arithmetic) and *dyspraxia* (i.e., difficulty in planning and coordinating body movements). In addition, children diagnosed with dyslexia are often affected by *Attention Deficit Hyperactivity Disorder* (ADHD), a neurodevelopmental disorder that is characterized, as the name suggests, by ongoing patterns of inattention and excessive hyperactivity. As concerns these non-linguistic disorders, Stella and colleagues (2009) found that a comorbidity with ADHD is present in 10,9% of dyslexic children, while comorbidity with *dyspraxia* is present in 26,1% of dyslexic individuals. Moreover, it is reported that approximately 44,6% of children with developmental dyslexia are also affected by *dyscalculia*.

Reading and spelling difficulties are widely acknowledged as the hallmark of dyslexia: however, individuals diagnosed with this developmental disorder exhibit more complex and widespread impairments that are not restricted to the linguistic domain but do also affect the attentional (Everatt et al. 1997, Hari et al. 1999) and the motor dimensions (Ramus et al. 2003, Nicolson and Fawcett 1990). Interestingly, as concerns linguistic-related competences, a consistent number of studies has reported that dyslexic subjects display significant impairments in both the phonological (Ramus et al. 2003, Rack et al. 1992, Brady et al. 1983, Elbro 1997, Desroches et al. 2006, Paulesu et al. 2001) and the morpho-syntactic domains (Bar-Shalom et al. 1993, Byrne 1981, Waltzman and Cairns 2000, Mann et al. 1984) , as well as in the vocabulary development (Scarborough 1990, Snowling et al. 2003, Denckla and Rudel 1976) and in the interpretative processes (Fiorin 2010, Vender 2011, 2017). The following sections will be devoted to an overview of these major linguistic manifestations of developmental dyslexia.

5.1.1 Linguistic manifestations of developmental dyslexia

The linguistic difficulties related to developmental dyslexia are not restricted to reading and spelling skills (§5.1.1.1): a number of studies has shown in fact that dyslexics manifest important phonological and phonology-related deficits (§5.1.1.2), as well as morpho-syntactic and interpretative impairments (§.5.1.1.3). In the following sections, these major linguistic impairments will be discussed.

5.1.1.1 Reading and spelling difficulties

As discussed in the previous section, the most remarkable impairment exhibited by dyslexics is the poor development of reading and spelling skills. As a matter of fact, a large number of studies has shown that dyslexic children have a poor reading fluency, characterized by a slow and effortful decoding process. The reading is also remarkably inaccurate: dyslexics struggle to discriminate between similar graphemes which differ in small orthographic details (e.g., *m*-*n*; *b*-*d*), as well as between graphemes corresponding to similar phonemes (e.g., the bilabial plosives *b* and *p*). In addition, the reading errors are not limited to the wrong decoding of single graphemes, but dyslexics often replace entire words (e.g., *then*) with similar-looking but unrelated ones (e.g., *when*) during reading. Significantly, dyslexics perform remarkably worse when they are asked to read unfamiliar words and non-words.

These reading difficulties can be interpreted following the Dual-Route Cascade (DRC) Model[88] of reading (Coltheart et al. 2001). In short[89], according to this computational model, the reading process can be achieved through two major routes – the lexical and the sub-lexical one. The lexical route processes each word as an indivisible unit, which is stored in the orthographic input lexicon along with its pronunciation. When the readers visually recognize a written word, they access the corresponding lexical entry and retrieve the information about its phonological form. Quite intuitively, the lexical route can be used to read familiar and more common words: however, it does not enable the reading of non-words, which cannot be stored in the orthographic input lexicon and do not have a semantic lexical entry. Non-words can be read exclusively through the sub-lexical route: letter strings are decomposed in smaller units (e.g., syllables, graphemes) that are subsequently pronounced by applying the orthographic-phonological conversion rules.

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[88]Implemented from the original proposal known as Dual-Route Model (Coltheart 1985, Humphreys & Evett 1985).

[89] For a more comprehensive description of the Dual-Route Cascade (DRC) Model (Coltheart et al. 2001) see Vender (2017).

The greater reading difficulty exhibited by dyslexics with non-words seems to indicate an impairment in the sub-lexical route that prevents the correct decoding of letter-sounds associations (Vellutino et al. 2004). Conversely, a better reading performance with familiar and common words suggests that dyslexics resort mainly to the lexical route to read words that they recognize as familiar thanks to some visual features (e.g., initial letters or syllables). Nonetheless, relying on visual cues does not guarantee a successful reading: rather, it might be a source of confusion, as evidenced by dyslexics' tendency to often replace similar-looking graphemes or words. Moreover, a series of findings reported by Ziegler et al. (2003) suggest that also the lexical route might be damaged, to some extent, in the dyslexic population. In this study, English- and German-speaking dyslexic children exhibited, in fact, two main reading impairments: first, they were remarkably slower in reading compared to both chronological and reading age-matched children; second, this reading difficulty was directly proportional to the stimulus length with both words and non-words. These findings suggest that dyslexic children resort to a letter-by-letter reading, typical of the sub-lexical route, also with more familiar and common words. Since this route is not working properly, their reading is extremely slow, inaccurate and effortful if compared to that of control children.

While an effortful and slow reading is cross-linguistically attested, reading errors are more frequent in languages with an opaque orthographic system. In line with what discussed in the previous section, a series of studies have shown that English-speaking dyslexic children have a low reading accuracy with both words and non-words (40%): this finding is particularly remarkable especially when compared to the ceiling performance of children speaking a more transparent language such as German or Italian (Wimmer 1993, Wimmer and Goswami 1994, Seymour et al. 2003). As far as concerns dyslexics' poor spelling skills, the findings from a number of studies suggest a significant parallelism with the reading difficulties discussed above (Bourassa and Treiman 2003, Friend et al. 2008, Plisson et al. 2013). In particular, Bourassa and Treiman (2003) reported that dyslexic children made significantly more misspellings with non-words than with words. This evidence suggests that dyslexic children adopt decoding strategies similar to those used in reading, and in line with the assumptions of the DRC Model (Coltheart et al. 2001). For the spelling of more frequent words, they resort to orthographic strategies in order to retrieve the word visual form, stored in the orthographic input lexicon. Nonetheless, this strategy does not enable the spelling of non-words, as it is impossible to resort to visual stored aspects of invented letter strings. Non-words can therefore be spelled exclusively through the sub-lexical route, by applying the orthographic-phonological conversion rules. In line with what observed for reading, dyslexics' better performance in the spelling of common words suggests that they mainly resort to the lexical route. This strategy, however, does not completely prevent spelling mistakes, as confirmed by dyslexics' poor spelling performance with common words compared to that of both chronological- and reading-age matched children (Plisson et al. 2013). On the contrary, the greater spelling difficulty with non-words seems to confirm an impairment in the sub-lexical route that prevents the correct application of the orthographic-phonological conversion rules.

To summarize, reading and spelling difficulties are the best-known manifestations of developmental dyslexia. Dyslexics exhibit poor reading and spelling fluency, both characterized by a slow and inaccurate decoding process. Quite interestingly, greater decoding difficulties are reported with unfamiliar words and non-words, suggesting that dyslexics have not completely automatized the correct decoding of grapheme-phoneme associations. As we will see in the following section, the difficulty exhibited by dyslexics in acquiring these systematic correspondences between orthography and phonology is attributable to the highly compromised phonological competence which characterizes the dyslexic population in its entirety.

5.1.1.2 Phonological and phonology-related deficits

An influential work by Ramus et al. (2003) has revealed that the entire population of dyslexics suffers from a compromised phonological competence. This impairment typically manifests as a lacking phonological awareness, a metalinguistic skill that allows individuals to analyse and deliberately manipulate the phonological structure of the words. It is in fact well attested by a large number of studies that dyslexics perform very poorly in those tasks requiring a conscious manipulation of speech units, such as the identification of initial, final and middle sounds of words, the detection and the production of rhyming words, the deletion and the replacement of phonemes in a given word, and the blending of syllables and sounds to create new words (among others, Bradley & Bryant 1983; Stanovich & Siegel 1994, Ramus et al. 2013, Desroches et al. 2006). Significantly, this phonological impairment persists into adulthood: despite a general improvement of their spelling and reading skills, dyslexic adults still obtain very low scores in tests assessing phonological awareness (Bruck 1992; Ramus et al. 2003; Wilson & Lesaux 2001, Paulesu et al. 2001), as well as in those tasks involving a taxation of the phonological processes, such as *non-word reading* and *word dictation under articulatory suppression* (among others, Ramus et al. 2003, Re et al. 2011).

These phonological deficits are considered to be responsible for the reading and spelling difficulties exhibited by dyslexics (Rack et al. 1992). An inadequate phonological awareness determines in fact dyslexics' inability to properly acquire and automatize the systematic grapheme-phoneme correspondences required for the decoding of words. In this respect, a number of studies has confirmed a strong correlation between phonological awareness and reading skills (Snowling 1995;

Blachman 1994, 1997, 2000; Rispens 2004), as well as between phonological awareness and the ability to recognize the letters of the alphabet (Bowey 1994; Johnston et al. 1996, De Jong and Van der Leij 1999). A poor phonological awareness is also significantly related to the greater reading and spelling difficulty manifested by dyslexics with non-words. As discussed in the previous section, the decoding of invented letter strings can in fact be accomplished exclusively by applying the orthographic-phonological conversion rules. Significantly, non-word reading represents an extremely critical task for both dyslexic children (Kamhi & Catts 1986; Rispens 2004) and adults (Ramus et al. 2003, Re et al. 2011, Elbro 1997, Brady et al. 1983), supporting the assumption that non-word decoding strongly depends on phonological processes.

Furthermore, a compromised phonological competence can also account for the vocabulary disorders often attested in dyslexics. A number of studies on dyslexic children has revealed that their vocabulary is often underdeveloped in comparison to that of age-matched typically developing peers. In addition, dyslexic children display a greater difficulty in acquiring long and infrequent words (Wolf & Obregon 1992, Scarborough 1990, Snowling et al. 2003). Further compelling evidence for an impaired vocabulary access in dyslexics comes from their low performance on rapid automized naming (RAN) tasks (Denckla 1972, Denckla & Rudel 1976). During the RAN test, participants are asked to name as fast as possible familiar items (e.g., objects, colours, letters, or digits) that are visually presented. It has been widely demonstrated that both adults and children with dyslexia are significantly slower than age-matched controls in picture naming[90] (Felton et al. 1990, Ghidoni & Angelini 2007, Wolf et al. 1986, Fawcett & Nicolson 1994, Willburger et al. 2008); moreover, dyslexic children perform even worse than reading age-matched controls (Denckla & Rudel 1976). These vocabulary impairments have been interpreted as a consequence of dyslexics' difficulty with both the storage and the retrieval of the phonological representation (i.e., syllables and sound structures) of the words (Ramus & Szenkovits 2008, but see Wolf et al. 2000 for an alternative explanation). Significantly, this assumption finds further confirmation in the fact that the lexical and vocabulary abilities of dyslexic adults result extremely impaired in those tasks involving a taxation of the phonological processes (e.g., *lexical decision under articulatory suppression*, Re et al. 2011).

To summarize, phonological deficits are largely attested in the dyslexic population, and they are persistent across ages. Given the direct impact of the phonological

[90] Fawcett and Nicolson (1994) reported a greater difficulty for dyslexics in picture naming when presented with objects rather than colours and alphanumeric stimuli. According to the authors, the reason for this discrepancy lies in the fact that the number of possible responses is considerably higher for objects than for digits, letters, and colours (which are a limited number). The difficulty in picture naming seems therefore proportional to the amount of processing required to retrieve the lexical information.

competence on writing and reading abilities, the impaired phonological awareness exhibited by dyslexics is held responsible for their well-attested reading and spelling deficits. Furthermore, phonological deficits are also associated with impaired lexical and vocabulary abilities.

5.1.1.3 Morpho-syntactic, semantic and pragmatic deficits

Although the phonological domain has long been the most investigated area in the research on developmental dyslexia, the linguistic deficits exhibited by individuals suffering from this disorder are not restricted to phonological and phonology-related abilities (e.g., reading and spelling skills). A number of studies has in fact demonstrated that dyslexics suffer also from an impaired grammatical competence, hampering their performance in tasks involving morpho-syntactic and semantic aspects of language. Significantly, this grammatical impairment manifests as a poor performance in the computation of specific and complex linguistic operations that, as we will see throughout the discussion, are particularly demanding in terms of processing resources.

Byrne (1981) investigated dyslexic children's comprehension of English *tough constructions* (1a), in which the surface subject of the main clause is the logical direct object in the embedded one. Note that the sentences reported in (1) have the same surface structure, but they differ in the underlying grammatical relations: in both sentences, the snake is the surface subject but, crucially, while in (1b) it is also the logical subject, in (1a) it represents the logical direct object of the biting.

(1) a. The snake is hard to bite
    b. The snake is glad to bite

Acquisition studies on typically developing children have revealed that sentences like (1a) are more difficult to interpret than sentences such as (1b). Younger children are not able to provide the correct interpretation of (1a) until the age of six: in fact, they tend to assign to the surface subject the logical role of the agent, by interpreting the snake as the agent of the action as in (1b). Significantly, this difficulty has been attributed to the higher degree of syntactic complexity of sentence (1a), which requires the computation of more complex syntactic dependencies[91] than sentence (1b), making the computation too demanding for young children's limited processing resources (Chomsky 1969, Cromer 1970).

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[91] In (1a) the logical role of subject is carried out by an arbitrary PRO which is not phonetically realized and gets a generic interpretation (Chomsky 1980), namely: The snake is hard [PRO] to bite. The sentence involves therefore the computation of two different syntactic dependencies: one between the silent subject PRO and the verb *to bite*, the other between the logical object *the snake* and the verb *to bite*. Conversely, (1b) involves only the computation of a dependency between the logical subject *the snake* and the verb (Byrne 1981).

The findings reported by Byrne (1981) showed that dyslexic children perform remarkably worse than age-matched peers in the interpretation of *tough sentence*s, as they tend to interpret the snake as the logical subject of sentence (1a) also during their first school years. In addition, when presented with an ambiguous sentence like (2), in which the surface subject can be interpreted either as logical subject or direct object, dyslexic children tend to interpret (2) as yielding a subject interpretation (1b). Conversely, age-matched controls provide an object interpretation, similarly to that assigned to the *tough sentence* in (1a).

(2) The snake is horrible to bite

Taken together, these findings indicate that, differently from age-matched peers, dyslexic children tend to always interpret the surface subjects as logical subjects. Interestingly, this linguistic behaviour resembles that displayed by younger children, suggesting that dyslexic children have a less mature grammatical competence than age-matched peers. As a consequence of more limited processing resources, dyslexic children have difficulty in providing the correct interpretation of *tough sentences* like (1a), which have a high degree of syntactic complexity.

Processing deficits have been held responsible also for the difficulties exhibited by dyslexics in the interpretation of relative clauses. A number of studies have demonstrated that dyslexic children are impaired in both the comprehension and the production of subject (3) and object (4) relative clauses, with a performance resembling that of younger children (Bar-Shalom et al. 1993, Stein et al. 1984, Sheldon 1974, Mann et al. 1984, Guasti et al. 2015, Pivi & Del Puppo 2014, Gibson 1991,1998). Significantly, the impairment displayed by dyslexics is more marked with object relatives than with subject relatives, and it persists into adulthood: in a study on Italian dyslexic young adults, Cardinaletti and Volpato (2015) found that dyslexics perform worse than age-matched controls in the production of object relatives, showing instead a performance similar to that of the adolescent control group.

(3) The lion that hits the bear rolls the ball
(4) The bear that the lion hits rolls the ball

Greater difficulties with object relatives in comparison to subject relatives have been attributed to the more complex syntactic configuration of the former: as a matter of fact, (4) involves the computation of long-distance syntactic dependencies[92], which are expensive in terms of processing costs (De Vincenzi

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[92] The syntactic construction of both (3) and (4) involves the extraction of a constituent which moves from its merge position to the highest node of the syntactic structure (CP). The difference between subject and object relatives lies in the position from which the constituent had moved: in the former

1991). As argued for *tough-sentences*, the parallelism between the performance of dyslexics and that of younger children strongly suggests that the impairments with relative clauses are attributable to limited processing capacities (Gibson 1991,1998, Grodner & Gibson 2005, Warren & Gibson 2002, Guasti et al. 2015, Cardinaletti & Volpato 2015).

Moreover, dyslexics have been found impaired with the interpretation of pronominal expressions. A study by Waltzman and Cairns (2000) has shown that eight-year-old dyslexic children have particular difficulties in the interpretation of coreferential pronouns, replicating the behaviour of younger typically developing children. When presented with a sentence like *Anna admires her*, dyslexic children tend to accept as grammatically correct the interpretation according to which Anna admires herself rather than another female person[93]. This inability to properly interpret coreferential pronouns is cross-linguistically attested in preschool children by acquisition studies on English (Chien & Wexler 1990), Russian (Avrutin & Wexler 1992), and Dutch (Philip & Coopmans 1996). Also in this case, the fact that dyslexics' interpretative behaviour resembles that of younger children (who have a less mature grammatical competence) provides convincing evidence for underdeveloped computational resources in the impaired population. In a more recent study, Fiorin (2010) has investigated dyslexics' interpretation of ambiguous sentences like (5), in which the pronoun *his* can be interpreted either as referring to the DP *Francesco* or to the *DP every friend*. Note that, in the former case, the pronoun *his* receives a binding interpretation($_j$), whereas in the latter a coreferential one($_k$)[94].

(5) Every friend$_j$ of Francesco$_k$ painted his$_{j/k}$ bike

In open contrast with the findings reported by Waltzman and Cairns (2000), the results by Fiorin (2010) revealed that dyslexic children are able to access both pronoun interpretations. However, differently from typically developing children, dyslexics tend to interpret the ambiguous sentences by constantly assigning the same pronominal reading across all the experimental items. This interpretative

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(3), it is extracted from the embedded subject position *The lion that hits the bear [the lion] rolls the ball*; in the latter (4), the extraction involves the constituent in the embedded object position *The bear that the lion hits [the bear] rolls the ball*. The syntactic dependency in (4) is longer because the constituent is moved from a more embedded position within the syntactic structure.

[93] Principle B of the Binding Theory (Chomsky 1981) states that a pronominal expression must be free in its governing category (i.e., the clause): hence, it cannot be bound with a c-commanding antecedent. In the sentence *Anna admires her*, the pronoun cannot refer to Anna, otherwise it would be bound within its local domain.

[94] Binding reading of sentence (5): for every x, if x is a friend of Francesco, then x painted x's bike
Coreferential reading of sentence (5): for every x, if x is a friend of Francesco, then x painted Francesco's bike

strategy adopted by dyslexics has been interpreted as evidence for a limitation in their computational resources. The process of ambiguity resolution is demanding in terms of processing resources, as it requires to evaluate two possible sentence interpretations: dyslexics would avoid this resource-consuming shifting by always assigning one of the two possible readings to the ambiguous sentences. In short, Fiorin (2010) showed that dyslexics are able to interpret coreferential pronouns: nonetheless, they display an interpretative behaviour that differs considerably from that of typically developing age-matched peers, probably due to their limited processing resources.

Further research on the syntactic abilities in developmental dyslexia has revealed that children with dyslexia manifest remarkable difficulties also in the interpretation of passive sentences, as they master both the comprehension and the production of passive constructions significantly later than typically developing peers (Reggiani 2010). In addition, they also manifest relevant morphosyntactic deficits, such as a poor sensitivity to subject-verb agreement violations (Jiménez et al. 2004), a weak morphological awareness[95] (Leikin & Hagit 2006), and an impaired inflectional morphology production (Joanisse et al. 2000).

Lastly, recent studies have also indicated that dyslexics experience more problems with pragmatic aspects of language comprehension than typically developing individuals (Griffiths 2007, Fiorin 2010, Vender 2011, 2017). Fiorin (2010) investigated the interpretation of the grammatical aspect of Italian past tenses Imperfective (6) and Present Perfect (7): as the name suggests, the former encodes an imperfective aspect, and it is used to describe ongoing and habitual situations occurring in the past; the latter, instead, encodes a perfective aspect, and describes concluded situations. Results indicate that dyslexic children perform significantly worse than age-matched controls in the interpretation of the imperfective grammatical aspect, by interpreting (6) as referring to a complete rather than an ongoing event.

(6) Marco mangiava il gelato
Marco ate.IPFV the ice-cream
Marco was eating the ice-cream

(7) Marco ha mangiato il gelato
Marco ate.PFV the ice-cream
Marco has eaten the ice-cream

Again, dyslexics' interpretative behaviour is in line with that displayed by younger peers: while five-year-old children are already able to correctly interpret the

[95] Morphological awareness can be defined as the understanding of how words can be broken down into smaller units of meanings such as roots, prefixes, and suffixes (Tighe & Binder 2015)

perfective grammatical aspect, they still consider sentences like (6) as appropriate for complete past events (Hollebrandse & van Hout 2001). According to Fiorin (2010), the interpretation of the imperfective past tense involves a more complex reasoning in comparison with that of simple past, as it requires the computation of a conversational implicature. If the speaker wanted to convey the message that the event of eating the ice-cream in (6) had been completed, they would have used the past tense, which is fully informative in this respect. Consequently, the use of the imperfective tense in (6) suggests that the action of eating was not yet concluded. This pragmatic evaluation of the imperfective grammatical aspect is arguably too demanding for younger children and dyslexics due to their limited processing resources. Further evidence for pragmatic impairments in developmental dyslexia comes from a series of experiments performed by Vender (2011, 2017): children with dyslexia manifest significant difficulties in the interpretation of sentences including anaphoric dependencies, as well as quantifiers, frequency adverbs and propositional connectives. Significantly, the comprehension of this type of sentences requires the computation of conversational and scalar implicatures[96], hence providing further support to the hypothesis of limited processing resources in dyslexics.

5.1.1.4 Concluding remarks

The linguistic deficits exhibited by dyslexics are not restricted to the well-attested reading and spelling difficulties, which can rather be considered as the most evident impairment of a more widespread and complex disorder. As a matter of fact, the entire population of dyslexics has been found to suffer from a compromised phonological competence: besides having a direct impact on reading and spelling abilities, phonological deficits are also associated with impaired lexical and vocabulary skills. Moreover, dyslexics also exhibit an impaired grammatical competence that hampers their performance in tasks involving morpho-syntactic, semantic, and pragmatic aspects of language. Significantly, dyslexics perform poorly in the computation of specific and complex linguistic operations which are particularly demanding in terms of processing resources (e.g., interpretation of *tough sentences*, relative clauses, pronominal expressions, grammatical aspect). This evidence, together with the observation that dyslexics' interpretative behaviour is often in line with that displayed by younger peers, suggests that their difficulties are determined by a deficit in their processing abilities.

Among the different theoretical frameworks proposed to account for developmental dyslexia, the *Working Memory Deficit Hypothesis* (McLoughlin

[96] Scalar implicatures are related to the Maxim of Quantity (Grice 1975): the assertion of a lower-ranking alternative (e.g., some) in an implicational scale (i.e., a set of ordered alternatives) implicates that the higher-ranking one (e.g., all) does not hold (Horn 1989, 1984).

1994, 2002, and further implementations in Fiorin 2010 and Vender 2011, 2017) considers the whole range of phonological, morphosyntactic, and interpretative deficits exhibited by dyslexics as attributable to their limited working memory capacity and processing resources. This proposal will be discussed in the following sections, as it constitutes the theoretical framework for our study on the relationship between developmental dyslexia and negation processing in chapter 6.

5.2 Developmental dyslexia and working memory

The range of linguistic deficits discussed in the previous section suggests that the difficulties exhibited by dyslexics can be traced back to a limitation in their processing resources, or, more specifically in their working memory capacity. In the following section, we will introduce the concept of working memory, discussing the most influential and well-known theoretical model outlined by Baddeley and Hitch (1974), and further implemented in Baddeley (2000). Then, in §5.2.2 we will provide an overview of the experimental evidence indicating a correlation between working memory impairments and dyslexia. Finally, in §5.2.3, we will present hypothesis originally proposed by McLoughlin and colleagues (1994, 2002), and subsequently implemented by Fiorin (2010) and Vender (2011, 2017), which suggests that developmental dyslexia and its major manifestations are crucially related to working memory inefficiencies.

5.2.1 Towards an updated model of working memory

Baddeley and Hitch (1974) define working memory as a multi-component system devoted to the temporary storage and manipulation of the information, which is required to carry out cognitive tasks such as reasoning, learning, and language comprehension. In the first formulation of what would become the most influential and well-known model[97], working memory consists of three distinct components

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[97] One of the first multistore models of memory was elaborated by Atkinson and Shiffrin (1968). According to their proposal, memory consists of three distinct stores: a sensory register, a short-term memory (STM), and a long-term memory (LTM). Significantly, the information would pass from one store to another following a linear fashion: first, it is processed by sensory organs to flow into STM, where it is temporarily maintained through rehearsal operations; then, the information flows into LTM for a long-term storage. In this view, the new information coming from the sensory register must necessarily pass through the STM to reach the final storage in the LTM: in turn, the retrieval of the information already stored in the LTM can be obtained only through the access to the STM. The major limitation of this linear model consists in its inability to account for experimental evidence showing that individuals with an impaired STM often exhibit an intact LTM, as the STM is considered the only access for the storage and retrieval of long-lasting information. The multi-component model proposed by Baddeley and Hitch (1974) overcame this intrinsic limitation due to the unitary and linear nature of the information storage assumed by Atkinson and Shiffrin (1968).

(Figure 5.1): an attentional controller (Central Executive), and two slave subsystems, one dealing with auditory and verbal information (Phonological Loop), the other dealing with visual and spatial information (Visuo-Spatial Sketchpad).

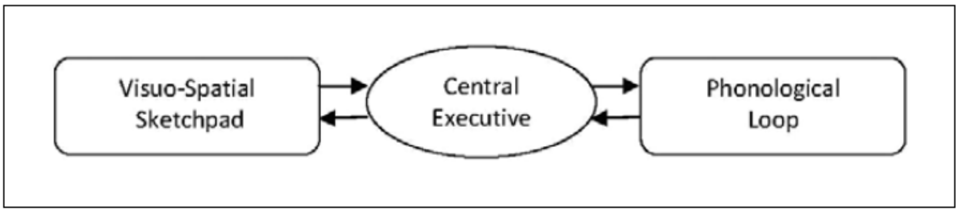

Figure 5.1. Baddeley and Hitch's (1974) tripartite model of working memory.

The Phonological Loop permits the temporary maintenance of the verbal material in the working memory. It consists of two independent subsystems, which are mainly controlled by the left hemisphere: a Phonological Store and an Articulatory Rehearsal Process. The Phonological Store is devoted to the temporary maintenance of acoustic and speech-based information: its storage capacity is limited in time, as the material is maintained only for about two seconds. The Articulatory Rehearsal Process performs two distinct functions: first, it converts visual material (e.g., written words or pictures) into a phonological code, so as to permit its temporary storage in the Phonological Store; second, it allows to enhance memory performance by refreshing the material maintained in the Phonological Store through subvocal repetition. Nonetheless, the Phonological Loop has a limited span: when the material to be refreshed by the subvocal rehearsal system increases considerably, the first chunks of information decay from the short-term Phonological Store before being refreshed again. This is precisely what happens when we cannot recall very long sequences of words or digits. The Phonological Loop is commonly referred to as the *verbal component* of the working memory, given its direct relation with language: in fact, it has been demonstrated that phonological memory is significantly involved in reading, writing, and spelling skills, as it allows the acquisition and subsequent automatization of the letter-sound correspondences (Colombo et al. 2009, Gathercole & Baddeley 1990, Gathercole & Baddeley 2014).

While the Phonological Loop deals with the linguistic material, the Visuo-Spatial Sketchpad allows the temporary maintenance and subsequent manipulation of visual and spatial information. This slave subsystem, which is mainly controlled by the right hemisphere, is deputed to the acquisition of visual semantics concerning information such as, for instance, the colours and the shapes of the objects. In addition, it is fundamental to the acquisition of spatial orientation and, more in general, geographical knowledge. Similarly to the verbal subsystem, the Visuo-Sketchpad has a limited storage capacity: however, little is known about its internal structure and possible further subdivisions.

The Central Executive is the most important component of the working memory. Nonetheless, in the original version of Baddeley and Hitch's model (1974), it is vaguely defined as an attentional system without storage capacity, that connects both the subsystems and the Long Term Memory. Its main functions are defined only later on (Baddeley 1986), and can be summarized as follows: i) the ability to focus and shift attention by inhibiting irrelevant stimuli; ii) the ability to distribute attention while performing different tasks; iii) creating an interface between Long Term Memory, Phonological Loop, and Visuo-Spatial Sketchpad.

The major limitation of the original tripartite model of working memory lies in its inability to explain how the material coming from the two slave subsystems can be integrated and manipulated with that already stored in the Long Term Memory, as the Central Executive is not conceived to have a storage capacity.[98] To solve this impasse, Baddeley (2000) introduces a fourth component of working memory, the Episodic Buffer, which can be defined as a storage system that connects bidirectionally the Central Executive and the Long Term Memory. The Episodic Buffer is conceived as an interface that is capable of integrating the visual, spatial, and verbal materials stored in the slave subsystems and retrieved from the Long Term Memory. In addition, it also permits the temporary storage and the manipulation of the information to form units or episodes (whence the name). However, due to the high computational demand of providing a simultaneous access to the different codes of information (i.e., phonological, visual and spatial), it has a limited storage capacity. In this updated version of the model, the Central Executive maintains its fundamental role of attentional controller, by focusing and dividing attention during the execution of cognitive tasks such as reading comprehension, problem solving, arithmetic and learning (Baddeley 2003).

[98] A further challenge for the original model proposed by Baddeley and Hitch (1974) was posed by studies showing that amnesic patients with an impaired Long Term Memory were able to immediately recall very long prose passages, which exceeded the storage capacity of the Phonological Loop. This evidence has suggested the existence of another mechanism enhancing their recall performance: crucially, such mechanism cannot be the Central Executive, as it is not supposed to have a storage capacity (see Vender 2017 for a detailed discussion of the clinical studies).

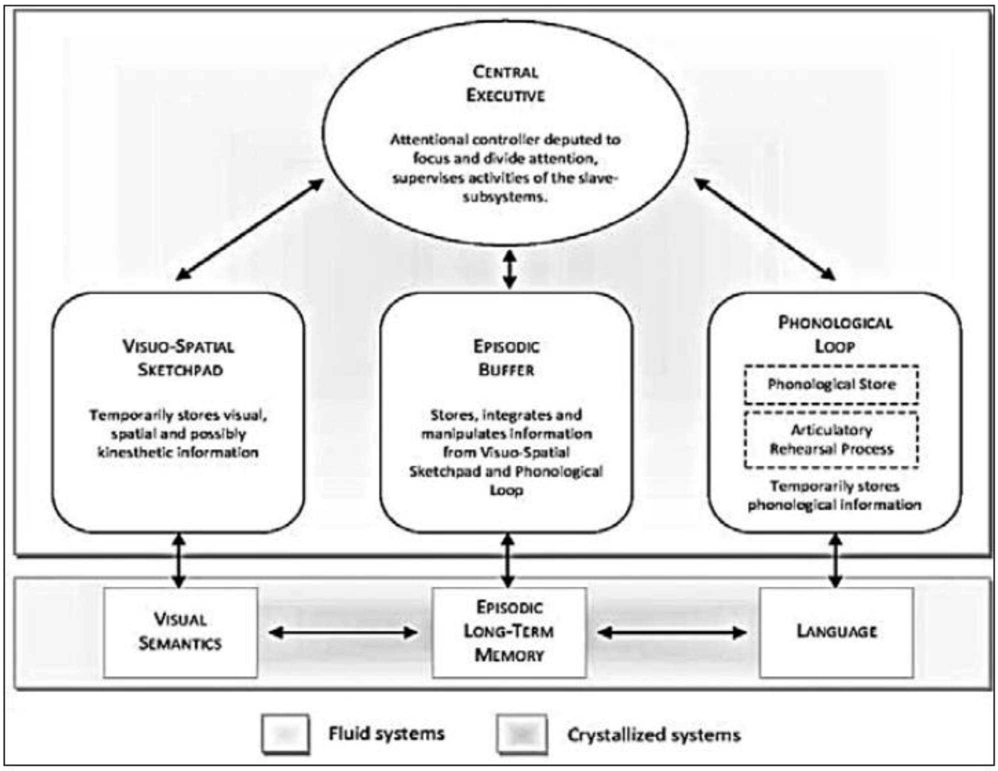

Figure 5.2. Baddeley's (2000) revised model of working memory.

To summarize, the revised model of working memory proposed by Baddeley (2000) is exemplified in Figure 5.2. The Central Executive is an attentional controller without storage capacity that supervises the activities of three distinct slave systems. The first is the Visuo-Spatial Sketchpad, deputed to the temporary storage of visuo-spatial information. The second is the Phonological Loop (consisting of the Phonological Store and the Articulatory Rehearsal Process), which temporary stores verbal information. The third is the Episodic Buffer, which has a storage capacity and allows to integrate and manipulate the information provided by the other subsystems via the Central Executive. In addition, the Episodic Buffer is conceived to have direct access to the Episodic Long Term Memory[99] so to integrate long-lasting information with the material provided by the other subsystems. Worth noting, Baddeley (2000) also draws an important distinction between fluid and crystallized memory: the former corresponds to the working memory, and refers to those cognitive abilities such as attention, temporary storage of information and problem-solving; the latter refers instead to cognitive functions associated with the acquisition of long-lasting and specific knowledge.

[99] Episodic LTM is deputed to the storage of specific facts and events from the past. Baddeley (2002) distinguishes the Episodic LTM from the Semantic LTM, where is stored generic encyclopaedic knowledge about the world.

5.2.2 Working memory limitations in developmental dyslexia

Working memory impairments are widely attested in individuals suffering from developmental dyslexia. A great number of studies has in fact reported lower-than-normal phonological and verbal abilities in both dyslexic adults (Ghidoni & Angelini, 2007, Alloway & Alloway 2013, Ghani & Gathercole 2013) and children (Jeffries & Everatt, 2004; Menghini et al. 2011, Poblano et al. 2000, Smith-Spark & Fisk, 2007, Swanson 1999, Hulme & Roodneys 1995, Helland & Asbjørnsen 2004). In addition, deficient executive functions have also been found: dyslexic children perform significantly poorer than typically developing peers in the simultaneous execution of different cognitive tasks (Wang & Gathercole 2013), as well as in the execution of tasks involving visual search, orientation, and requiring to focus, shift or inhibit their attention (Brosnan et al. 2002, Facoetti et al. 2000, 2003, Menghini et al. 2010). Crucially, Jeffrey and Everatt (2004) showed that, while dyslexic children are remarkably impaired in both phonological and central executive measures, their performance resembles that of age-matched controls in the execution of visuo-spatial and visual-motor coordination tasks. Taken together, these findings strongly suggest that the working memory impairments exhibited by dyslexics are restricted to the Phonological Loop and the Central Executive components, whereas the Visuo-Spatial Sketchpad appears to be undamaged.

Besides the well-attested relationship between the verbal working memory capacity and the proper development of reading, writing and spelling skills (Colombo et al. 2009, Gathercole & Baddeley 1990, Gathercole & Baddeley 2014, Jarrett 2009), several studies have reported a significant correlation between verbal working memory and the impaired linguistic competence exhibited by dyslexics (§5.1.1.3). As concerns morphosyntactic competence, Rispens and Been (2007) found that dyslexic children's poor sensitivity to subject-verb agreement violations is strictly related to their limited phonological working memory capacity. As concerns sentence comprehension, significant correlations have been reported between dyslexics' limited working memory resources and their difficulties in interpreting complex or ambiguous syntactic structures such as *tough sentences*, passive or relative clauses (Wiseheart et al. 2009, Kim & Christianson 2013, Sprouse et al. 2012). In a quite recent study, Robertson & Joanisse (2009) investigated how syntactic complexity and task-related working memory load might affect sentence comprehension by dyslexic and normal readers. Interestingly, the results reported an overall worse performance by both groups as the working memory load increased: however, dyslexics exhibited a more substantial impairment in the interpretation process compared to the control group. Lastly, other studies have pointed out the relationship between a lower-than-normal verbal working memory capacity and the difficulties exhibited by dyslexics in the retrieval of lexical information (Gadsby et al. 2008, Leclercq & Majerus 2010, Majerus et al. 2008). Interestingly, phonological working memory seems to be involved also in the learning of a second language, affecting the acquisition of both vocabulary and grammar (Martin 2013, Andersson 2010, Ramus & Szenkovits 2008).

To summarize, a large number of studies have provided compelling evidence that individuals with developmental dyslexia display working memory deficits. This impairment, which persists into adulthood, does not affect all the working memory components, but only those related to the linguistic and central executive domains (i.e., Phonological Loop and Central Executive). Significantly, important correlations have been found between impaired verbal working memory skills and the wide range of linguistic impairments exhibited by dyslexics and discussed in detail in §5.1.1. In the following section, we will see how this experimental evidence has led towards the formulation of the *Working Memory Deficit Hypothesis* to account for the deficits observed in dyslexic subjects.

5.2.3 The Working Memory Deficit Hypothesis

Over the past few decades, researchers have proposed different theories to account for the underlying cause of developmental dyslexia and its wide-ranging manifestations. Based on neurobiological evidence, the proponents of the *Magnocellular Deficit Hypothesis* claim that dyslexia is caused by abnormalities found in the brain of dyslexics within the visual and auditory magnocellular pathway (Stein & Walsh 1997, Stein 2001). These auditory and visual impairments would be the source of a reduced sensitivity to rapidly changing stimuli, and have been held responsible for the poor reading and spelling skills exhibited by dyslexics. However, if on the one hand these sensory deficits can explain dyslexics' impaired phonological competence and underdeveloped reading and spelling skills, on the other they cannot provide a satisfactory explanation for the well-attested vocabular, grammatical and attentional impairments. As the name suggests, the *Phonological Deficit Hypothesis* considers a deficit in the representation and processing of speech sounds as the underlying cause of developmental dyslexia (Ramus et al. 2003, Snowling 2000). According to the researchers, dyslexics' difficulties with the representation, storage, manipulation and retrieval of speech sounds would explain their phonological, reading and spelling impairments. However, similarly to the *Magnocellular Deficit Hypothesis*, it remains unclear how a specific phonological impairment can account for the other linguistic and attentional disorders exhibited by dyslexics. The proponents of the *Double-Deficit Hypothesis* (Bowers & Wolf 1993) claim, instead, that developmental dyslexia is characterized by two core disorders: besides the well-recognized phonological impairment, dyslexics would also experience a naming-speed deficit, which causes remarkably difficulties in rapid naming tasks. If on one hand the *Double-Deficit Hypothesis* can account for both phonological and lexical deficits, on the other it does not provide a satisfactory explanation for dyslexics' impaired grammatical competence and attentional disorders. Given their minor relevance to the aim of the present discussion, these proposals will not be further discussed. Nevertheless, it is worth noting that none of the theoretical frameworks outlined above can adequately account for the whole range of the linguistic and attentional deficits typically associated with developmental dyslexia.

As discussed in the previous section, working memory impairments are well documented in dyslexia, and they affect, in particular, the linguistic and the executive domains. This evidence, together with the significant correlations reported between impaired working memory skills and the linguistic deficits displayed by dyslexics, has led towards the formulation of the so-called *Working Memory Deficit Hypothesis*. McLoughlin and colleagues (1994, 2002) were the first to suggest that working memory impairments can be held responsible for the entire range of linguistic and attentional deficits attested in dyslexia. In particular, these impairments would affect the capacity of the Phonological Loop and the Central Executive components: while phonological and phonology-related deficits (§5.1.1.2) can be attributed to the inefficiency of the former, the processing of demanding linguistic operations (§5.1.1.3) would hamper the correct functioning of the latter.

The original hypothesis outlined by McLoughlin and colleagues (1994, 2002) has been further developed by other researchers, who aimed to provide an exhaustive explanation for the linguistic difficulties exhibited by dyslexics, in particular as regards the processing of complex syntactic constructions. In his proposal, formalized as the *Verbal Working Memory Deficit Hypothesis*, Fiorin (2010) suggests an implementation of Baddeley's model of working memory (2000) in order to account for the entire range of verbal impairments deficits shown by dyslexics. Fiorin draws an important distinction between the two subcomponents of the Phonological Loop: while the Phonological Store, as the name suggests, is devoted to the temporary storage of the phonological information, the Articulatory Rehearsal Process is held responsible for the access to this material in order to restore it and make it available to the other subsystems for further computations. According to Fiorin, dyslexics would suffer from an impairment in the Articulatory Rehearsal Process that prevents the access to the stored phonological material causing the well-attested phonological, reading and spelling deficits. Furthermore, the author introduced a new working memory component, the Grammatical Loop, which is deputed to the temporary storage and manipulation of the grammatical information. Similarly to what assumed for the Articulatory Rehearsal Process, a disrupted access to this grammatical material would explain those linguistic deficits related to morpho-syntactic, semantic and interpretative aspects of sentence processing. All in all, the *Verbal Working Memory Deficit Hypothesis* can account for dyslexics' poor phonological awareness and underdeveloped reading and spelling skills, as well as for their impaired grammatical competence. However, if on the one hand this model offers an exhaustive explanation for the verbal manifestations of dyslexia, on the other it does not take into consideration the well-attested attentional deficits shown by dyslexics, which confirm the presence of Central Executive impairments (among others, Everatt et al. 1997, Hari et al. 1999, Jeffrey & Everatt 2004).

To overcome this limitation, Vender (2011, 2017) proposes the so-called *Phonological and Executive Working Memory Deficit Hypothesis*. Unlike in Fiorin's model of working memory (2010), Vender does not need to postulate the existence of a specific subsystem deputed to the processing of the grammatical information in order to explain dyslexics' impaired linguistic competence. Starting from the observation that dyslexics underperform in comparison to age-matched controls in all the phonological and executive measures (among others, Vender 2011, 2017, Wang & Gathercole 2013, Jeffrey & Everatt 2004), she suggests that both the Phonological Loop and the Central Executive are severely damaged in dyslexics. Crucially, this impairment of the phonological and executive domains would be able to account for all the linguistic and attentional deficits attested in dyslexia. On one hand, an impaired Phonological Loop is held responsible for dyslexics' poor phonological awareness and their difficulty in properly acquiring reading and spelling skills. On the other, a disruption in the Central Executive domain prevents dyslexics from accomplishing complex linguistic tasks that are particularly demanding in terms of processing resources (e.g., interpretation of *tough sentences*, relative clauses, pronominal expressions, grammatical aspect, interpretation of scalar implicatures, see §5.1.1.3). In addition, the limited processing capacity of the Central Executive does also account for their well-attested difficulties with the execution of dual tasks, as well as with those concerning attention (Brosnan et al. 2002, Facoetti et al. 2000, 2003, Menghini et al. 2010). Altogether, the *Phonological and Executive Working Memory Deficit Hypothesis* provides an exhaustive explanation for all the deficits attested in dyslexia by assuming an impairment in the Phonological Loop and in the Central Executive domains. As concerns the linguistic manifestations, this model clearly predicts that dyslexics display remarkable difficulties with all those tasks that require a phonological analysis (e.g., phonological awareness tasks, reading, and spelling, see §5.1.1.2) or that are more demanding in terms of processing resources (e.g., sentence comprehension and production, see §5.1.1.3).

To summarize, different models have been developed to account for the underlying cause of developmental dyslexia: however, most of them seem unable to explain the entire range of deficits associated with this disorder. The *Working Memory Deficit Hypothesis*, originally outlined by McLoughlin and colleagues (1994, 2002), considers dyslexia as related to specific limitations of the working memory capacity and processing resources. Significantly, in its subsequent implementation by Vender (2011, 2017), this proposal offers an exhaustive explanation for all the phonological, morphosyntactic interpretative, and attentional impairments shown by dyslexics. Our study investigating the processing of sentential negation in dyslexia falls within this theoretical framework. The following section will be dedicated to a brief review of the few literature exploring the relationship between working memory resources, developmental dyslexia and negative sentence comprehension. This, together with what emerged from our first experiment on negation processing with typically developed adults (§4), will constitute the starting point for our follow-up study in chapter 6.

5.3 Negation processing in developmental dyslexia

Although the processing of sentential negation has been extensively studied in psycholinguistic research (see §2 for a detailed discussion), only a few and quite recent studies have been conducted on individuals diagnosed with developmental dyslexia to investigate negation processing in this atypical population. To the best of the author's knowledge, the first experimental study within this line of research was conducted by Vender and Delfitto (2010), who investigated the interpretation of negation in Italian dyslexic children. In this study[100], the authors developed a sentence-picture verification task to test how dyslexic children interpret negative sentences in comparison with typically developing age-matched peers. Participants were first presented with sentences including external (9) and internal (8) sentential negation. Then, they were asked to evaluate the truthfulness of the experimental sentences against different pictures, matching either the negated situation (e.g., the hen reading the newspaper) or the actual one (e.g., the hen doing shopping).

(8) The hen is not reading the newspaper
(9) It is not true that the hen is reading the newspaper

Results showed that dyslexic children significantly underperformed the age-matched controls in interpreting negative sentences, as indicated by higher error rates in both the true negative (i.e., picture matching the actual situation) and false negative (i.e., picture matching the negated situation) conditions. Moreover, a negation-by-truth-value effect was found, with true negative sentences being the most difficult to compute. Lastly, the type of negation (i.e., internal or external) did not affect the performance of neither group: this latter evidence is in line with previous findings pointing to some common features underlying negation

[100] The study by Vender and Delfitto (2010) consisted of a total of four experiments, with the aim to assess the comprehension of different negative constructions: in addition to the negative sentences discussed in the text, the authors also investigated the computation of (i) negative passive constructions, (ii) sentences including negative quantifiers, and (iii) negative concord constructions. Given our major interest in the processing of sentential negation, the reader might refer to Vender and Delfitto (2010) and Vender (2017) for a detailed discussion of the other negative constructions and the related relevant findings.

processing, regardless of what the negative marker takes under its scope (Wason 1961, Carpenter & Just 1975). Taken together, these results clearly indicate that dyslexic children face difficulties in the interpretation of negative sentences, showing a less accurate, but not slower, performance in comparison to typically developing children. The authors interpreted these results as consistent with the Two-Step Simulation Hypothesis (Kaup et al. 2007), which maintains that the processing of negative sentences is inherently more demanding than that of affirmatives: as a matter of fact, it requires the construction of two different mental simulations (i.e., the negated and the actual state of affairs), both of which must be momentarily maintained in the short-term memory for a later comparison, allowing the parser to grasp the sentence negative meaning (see §2.2.1.3). In the false negative condition, the comprehender benefits from being presented with a picture depicting the negated situation, that corresponds to the mental simulation under construction. Conversely, in the true negative condition, the picture represents instead the actual situation, and the parser must therefore construct ex novo the simulation of the negated information. This computation is remarkably demanding in terms of processing resources, and can explain the greater difficulties reported with true negative sentences.

According to the authors, the difficulties exhibited by dyslexics in processing negation are attributable to limitations in their working memory capacity, as predicted by the *Working Memory Deficit Hypothesis* (§5.2.3). As mentioned, the processing of negative sentences is considered particularly demanding in terms of processing costs, due to the nature of the mental simulations involved in the computation. In addition, the sentence-picture evaluation required to accomplish the task introduces an additional processing load, that makes the interpretation of negative sentences, and in particular that of true negatives, even more demanding in terms of computational resources. Following this line of reasoning, dyslexics would fail in negative sentence comprehension due to their limited processing resources, which are not efficient enough to cope with a too demanding linguistic operation. This assumption finds further confirmation in the fact that control children carried out the task without making a remarkable effort. Worth noting, evidence suggesting a relationship between working memory resources and negative sentence processing has been put forward by Deutsch et al. (2006), who claimed that the computation of negative sentences is particularly demanding when working memory resources are overloaded (see § 2.2.1.3 for a more detailed discussion).

To summarize, Vender and Delfitto (2010) reported compelling evidence that dyslexic children display significant difficulties with the comprehension of negative sentences. This interpretative deficit would be due to their limited working memory capacity, which prevents dyslexics from carrying out complex linguistic operations that are particularly effortful in terms of processing resources. However, this work presents two important limitations. First, similarly to Lüdtke et al. (2008)'s ERP study (see §2.2.1.3), the experimental design does not provide a pragmatically supportive context for the true negative condition: namely, the picture matching the negated situation is not mentioned in the sentence, producing a sense of pragmatic inadequacy (Wason 1965). The greater processing difficulties reported for true negative sentences may simply represent the consequence of an unsupportive context of utterance, which forces the parser to adjust the lacking contextual information. Second, affirmative sentences were presented as filler items: as a consequence, their interpretation was not analysed nor compared with that of the negative sentences. Therefore, it cannot be excluded that dyslexic children's difficulties with sentence interpretation are not attributable to the computational cost of negation: rather, they might be evidence of a more general processing impairment, triggered by the complexity of the sentence-picture verification task.

Scappini et al. (2015) conducted an ERP study to investigate the comprehension of affirmative and negative sentences in Italian dyslexic adults and controls. In a classical sentence-picture verification set-up, participants were asked to determine the truthfulness of affirmative and corresponding negative statements against a visual scenario. In order to avoid pragmatic infelicity, each test sentence was paired with the picture of two characters carrying out two different activities, so that both the action and the subject described in the test sentence were always present in the discourse context. Behavioural results showed that, despite a supportive context of utterance, negative sentences were more difficult to process than the corresponding affirmatives for both dyslexics and controls. Moreover a negation-by-truth-value interaction was reported in both groups, with the true negative being the most difficult condition. These results have been interpreted as evidence for a non-incremental processing of negation. However, dyslexics performed remarkably worse than controls in the comprehension of both affirmative and negative sentences, as revealed by slower response times and higher error rates in all the four experimental conditions. This evidence does not corroborate the hypothesis that negation constitutes a specific source of processing difficulty for dyslexics, as assumed by Vender and Delfitto (2010): rather, it suggests a general computational impairment caused by the complexity of the experimental task.

As concerns the ERP results, the analysis revealed that dyslexic adults displayed different ERP modulations for both affirmative and negative sentences compared to the normal adult readers. In line with previous ERP-EEG studies, larger N400 amplitudes were reported for controls in the false affirmative and the true negative condition, providing further confirmation for the Two Step Simulation Hypothesis[101] (see Fischler et al. 1983, Lüdtke et al. 2008). Instead, dyslexic adults

[101] In the true negative condition, the picture represents the actual situation described in the sentence. Larger N400 modulations have been taken as evidence that, at the early stages of negative sentence

displayed different ERP modulations for the very same conditions, which cannot be traced back to the N400 effect reported for controls: true negative sentences elicited a broadly distributed negativity, whereas no N400 effects were reported for false affirmatives.

If, on the one hand, behavioural results do not confirm that dyslexics' deficits in sentence comprehension are triggered by negation, on the other hand ERP findings suggest that this might be related to the fact that dyslexics interpret negative sentences by relying on different cognitive processes than those assumed by the Two-Step Simulation Hypothesis. As discussed, a non-incremental two-stage processing is particularly taxing in terms of computational resources, as it requires the temporary maintenance of two distinct mental simulations in the short-term memory for their subsequent comparison. Given their limited processing resources, dyslexics would adopt alternative and less demanding processing strategies with the aim of reducing this considerable working memory load required for the interpretation of negative sentences. Quite interestingly, the activation of compensatory strategies in subjects suffering from working memory impairments has been reported in previous literature (Hulme & Roodnerys 1995, Schlösser et al. 2006): in particular, Hulme and Roodnerys (1995) found that individuals can compensate their procedural difficulties by relying more consistently on unimpaired computational resources, thanks to their high IQ score. However, the fact that dyslexics performed significantly worse than controls in interpreting negative sentences seems to suggest that the alternative processing strategy employed by dyslexics is not adequate to compensate for their working memory limitations, which prevent them from copying with too demanding linguistic computations.

To summarize, Scappini et al. (2015) found that negative sentences were more difficult to process than affirmatives for adults with and without dyslexia, as predicted by the Two-Step Simulation Hypothesis (Kaup et al. 2007). However, dyslexics performed remarkably worse than controls regardless of sentence polarity: this behavioural evidence does not provide, therefore, direct support to the assumption that negation is a source of processing difficulty for dyslexics (Vender & Delfitto 2010). Nonetheless, the ERP findings suggest that dyslexics adopt different cognitive strategies in processing negative sentences, to arguably reduce the working memory load required for a non-incremental interpretation of negation. However, the adoption of alternative processing strategies would not be enough to overcome their working memory limitations: as a consequence, dyslexics would fail in the comprehension of negative sentences, as confirmed by behavioural data. For the aim of the present discussion, it is worth noting that dyslexics manifested

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processing, the comprehender is constructing the mental simulation of the negated situation, since negation has not been yet integrated in the interpretation process (see §2.2.1.3 for a detailed discussion of ERP-EEG studies investigating negation processing).

interpretative difficulties and unusual ERP modulations also with affirmative sentences. Within this general framework, we cannot exclude the possibility that the pattern of behavioural and ERP findings reported for dyslexics might merely reflect an experimental artifact of the truth-value judgment set-up, which worsens their overall performance by introducing an additional processing load to the task execution.

Similar findings were reported by Hu et al. (2018), who deployed a truth-value judgment task to investigate the comprehension of affirmative and negative sentences by young Chinese poor readers and age-matched typical readers. The results showed that negative sentences were harder to process than the corresponding affirmatives for both groups of readers, providing further confirmation for a non-incremental processing of negation. Furthermore, in line with the results reported by Scappini et al. (2015), Chinese poor readers displayed greater difficulties than controls in the comprehension of both affirmative and negative sentences, as indicated by higher error rates and response latencies. The authors interpreted these findings as evidence that children with reading disabilities face some general processing difficulties which are arguably attributable to the additional processing load introduced by the experimental task and not by the computation of linguistic negation.

However, this study has important experimental limitations. First, the Chinese children who took part in the experiment were not diagnosed with a specific reading disability nor with developmental dyslexia[102]. Quite intuitively, although these findings resemble those reported by Scappini et al. (2015), they cannot be taken as cross-linguistic evidence for negation processing difficulties in the dyslexic population. Second, behavioural results (i.e., accuracy and response times) suggest that negation is not a specific source of interpretative difficulties for poor readers: however, this experimental evidence did not allow researchers to grasp possible qualitative differences in the processing strategies adopted by poor readers to reduce the cognitive load of negation processing, as assumed by Scappini et al. (2015).

5.4 Concluding remarks

In the previous section, we have discussed the few studies dealing with the relationship between developmental dyslexia, working memory resources and the comprehension of negative sentences. Interestingly, this experimental evidence speaks in favour of a non-incremental strategy of negation processing, as predicted

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102 Inclusion criteria were lower-than-average scores on the literacy test assessing character recognition, vocabulary knowledge, and difficulties in writing and reading Chinese (Leong & Ho 2012)

by the Two-Step Simulation Hypothesis (Kaup et al. 2007). In fact, the behavioural results of both dyslexic and normal readers provide striking evidence that: i) negative sentences are more difficult to comprehend than the corresponding affirmatives (Scappini et al. 2015, Hu et al. 2018); ii) the true negative condition is the most difficult to process (Vender & Delfitto 2010, Scappini et al. 2015, Hu et al. 2018). The Two-Step Simulation Hypothesis accounts for the overall processing difficulties found in negative sentences (i), as well as for the negation-by-truth value interaction (ii) reported across behavioural and EEG studies deploying sentence-picture verification tasks. More precisely, it maintains that the processing of negative sentences is inherently more demanding than that of the corresponding affirmatives, as it involves the construction of two different simulations (i.e., the negated and the actual state of affairs), that are momentarily maintained in the working memory for a later comparison. In addition, the greater processing difficulties reported for true negative sentences are due to the fact that the parser must construct ex novo the simulation of the negated situation, unlike in the false negative condition where this information can be easily retrieved from the visual scene (see §2.2.1.3 for a detailed discussion).

Vender and Delfitto (2010) found that dyslexic children performed significantly worse than age-matched controls in the comprehension of negative sentences. This processing difficulty has been attributed to limitations in their working memory capacity, which prevent dyslexics from accomplishing complex linguistic operations that are particularly demanding in terms of computational resources (McLoughlin et al. 1994, 2002, see §5.2.3). Scappini et al. (2015) extended the investigation to the comprehension of both affirmative and negative sentences. Interestingly, behavioural data showed that adults with dyslexia underperformed in comparison to controls regardless of sentence polarity. Significantly, these findings pose a challenge to the assumption that negation constitutes a specific source of processing difficulty for dyslexics, as claimed by Vender & Delfitto (2010). Rather, they suggest a more general processing impairment, that is arguably related to the complexity of the sentence-picture verification process: as a matter of fact, this operation introduces a significant processing load, which makes the task execution too demanding for the dyslexics' limited working memory resources. In line with this behavioural evidence, Hu et al. (2018) reported a general difficulty with the comprehension of both affirmative and negative sentences by young Chinese poor readers in comparison to age-matched typical readers. Again, these results have been interpreted as evidence of a general processing impairment caused by the interplay between poor readers' working memory inefficiency and the task complexity.

Nonetheless, as discussed in §3.4, it is worth noting that behavioural measures of sentence comprehension (i.e., response choices and reaction times) do not provide any relevant insight on the ongoing cognitive mechanisms underlying sentence processing in subjects with and without dyslexia. In this respect, Scappini et al. (2015) found that dyslexics displayed different ERP modulations for negative sentences in comparison to the control group. If behavioural results do not point to negation as a specific source of processing difficulty for dyslexics, the ERP findings suggest that this might be due to the fact that they exploit alternative cognitive processes during negative sentence comprehension so to reduce the considerable working memory load required for a non-incremental computation of negation. However, this compensatory strategy would not be efficient enough to compensate for their working memory limitations, resulting in a poor interpretative performance. Although alternative cognitive strategies might be used to overcome specific procedural impairments (Hulme & Roodnerys 1995, Schlösser et al. 2006), it is important to underline that Scappini et al. (2015) found atypical ERP modulations also for affirmative sentences. Therefore, the ERP findings reported for negative sentences cannot be taken as conclusive evidence for an alternative strategy of negation processing: on the contrary, the entire pattern of unusual ERP modulations found for dyslexics might be merely the consequence of a too demanding experimental task, which affected their overall performance of sentence interpretation regardless of sentence polarity.

To conclude, previous research has provided conflicting evidence on whether negation represents a source of processing difficulties for individuals with developmental dyslexia. This is in part related to intrinsic methodological limitations of the sentence-picture verification tasks deployed so far to investigate sentence comprehension in this population: due to their behavioural nature, these tasks cannot provide any relevant insights on the online cognitive mechanisms underlying negative sentence processing; moreover, the accomplishment of metalinguistic judgments might have a negative impact on the overall linguistic processing, as it requires a greater exploitation of the parser's working memory resources. As a consequence, it is unclear whether the processing difficulties manifested by dyslexics and reported in literature are related to specific aspects of the linguistic processing or they are rather the result of an experimental artifact. As we will see in the next section, our follow-up study aims at disentangling the relationship between working memory resources, developmental dyslexia and negation processing by overcoming these methodological limitations.

5.5 Rationale and research questions

Besides the well-attested reading and spelling difficulties (§5.1.1.1), individuals with developmental dyslexia manifest a wide range of impairments, affecting not only the linguistic but also the attentional and the motor domain. As regards the linguistic manifestations of the disorder, dyslexics suffer from a compromised phonological competence, which has a direct impact on their reading and spelling abilities, but also affects their lexical and vocabulary skills (§5.1.1.2). Furthermore, dyslexics exhibit a weak grammatical competence, as attested by a poor performance in the execution of tasks involving morpho-syntactic, semantic and pragmatic aspects of language comprehension and production (§5.1.1.3): in particular, dyslexics have significant difficulties in the computation of specific linguistic operations, which are remarkably demanding in terms of processing costs (e.g., interpretation of binding principles, relative clauses and scalar implicatures).

Among the different theories proposed to account for developmental dyslexia, the *Working Memory Deficit Hypothesis* (McLoughlin et al. 1994, 2002), and its implementation by Vender (2011, 2017), argues that deficits in the phonological and central executive working memory components can be held responsible for the entire range of linguistic and attentional impairments shown by dyslexics (§5.2.3). This assumption is corroborated by the fact that working memory deficits are well documented in the dyslexic population: moreover, significant correlations have been reported between impaired phonological and executive memory skills and the different linguistic deficits exhibited by dyslexics (§5.2.2).

Currently, there is little psycholinguistic research dealing with the relationship between developmental dyslexia, working memory resources, and the comprehension of negative sentences. The studies discussed in §5.3 provide consistent evidence for a non-incremental view of negation processing, along the lines of the Two-Step Simulation Hypothesis (Kaup et al. 2007). This model considers the processing of negative sentences as more demanding than that of affirmatives, as it requires the construction of one more mental simulation (i.e., the negated situation) in comparison to the corresponding positive statement (§2.2.1.3). Throughout the discussion, we have seen that all these studies interpreted their results by assuming that dyslexics' processing difficulties are related to limitations in their working memory capacity, which prevent them from accomplishing too demanding linguistic operations.

Nonetheless, these works provided controversial evidence on whether negation constitutes a specific source of processing complexity for dyslexics. On one hand, Vender and Delfitto (2010) found that dyslexic children have significant difficulties in interpreting negative sentences, and they argue that this difficulty in sentence comprehension is rooted in the high computational demand of a non-incremental processing of negation. On the other hand, Scappini et al. (2015) found evidence that dyslexic adults are impaired in the comprehension of both affirmative and negative sentences, suggesting a more general processing difficulty that might be related to the experimental complexity of the sentence-picture verification set-up. Similar evidence has been reported by Hu et al. (2018) for Chinese children with reading difficulties. Furthermore, on the basis of their ERP findings, Scappini et al. (2015) suggested that dyslexics might adopt alternative processing strategies during negative sentence comprehension, in order to reduce the excessive working memory load required for a non-incremental computation of negation. However, both behavioural and ERP results must be interpreted with caution, as they might be biased by the complexity of the experimental set-up. Indeed, the sentence-picture evaluation required to accomplish the task introduces an additional processing load, which might have a negative impact on the overall sentence comprehension process.

To summarize, previous research does not provide conclusive evidence on whether negation constitutes a specific source of processing difficulty for dyslexics. This is in part due to important methodological limitations of the experimental set-up adopted so far to investigate sentence comprehension. As a matter of fact, a sentence-picture verification set-up: i) does not provide any relevant insights on the cognitive mechanisms underlying the online processing of negation in dyslexic and non-dyslexic subjects; ii) introduces an additional computational load which might bias dyslexics' interpretative strategy.

Based on these premises, we will conduct a follow-up of our visual-world study on negation processing described in chapter 4, with the aim of deepening the relationship between dyslexia, working memory resources and negative sentence comprehension. The deployment of an identification task with eye recording will allow us to assess the final sentence comprehension and provide, at the same time, unbiased fine-grained information on the ongoing cognitive processes underlying the comprehension of negative sentences in dyslexic and typical subjects. By means of this original experimental protocol, we will understand whether the difficulties in sentence comprehension shown by dyslexics are related to specific aspects of the linguistic processing or whether they are rather attributable to an experimental artifact of the sentence-picture verification set-up. In addition, relevant insights will be provided as concerns possible alternative processing strategies adopted by dyslexics during negative sentence comprehension.

To conclude, our follow-up study on the processing of sentential negation in developmental dyslexia aims to answer the following research questions:

i) is negation a source of processing difficulty for dyslexics?

In our first study (§4), we reported compelling evidence indicating that the computation of negation is a significant source of processing difficulty for normal adult readers. In particular, the processing costs traditionally attributed to negative sentences are arguably determined by the need to retrieve the negated information, which must be activated and then subsequently inhibited in order to interpret the sentence negative meaning. This evidence speaks in favour of a non-incremental processing of negation, arguing that negative sentences are inherently more difficult to process than the corresponding affirmatives because they require the computation of two different mental simulations.

The comparison of the looking pattern behaviour between dyslexic and normal readers during the real-time interpretation of affirmative and negative sentences can provide relevant insights on what hinders sentence interpretation in dyslexics. If negation constitutes a particular source of processing difficulty for dyslexics, we are expecting a delay in target identification in comparison to controls only in the negative condition. Otherwise, if dyslexics are affected by a more general processing impairment, we are expecting an overall delay in target identification in comparison to controls regardless of sentence polarity.

ii) do dyslexics adopt alternative processing strategies during negative sentence comprehension in comparison to normal adult readers?

The comparison of the looking pattern behaviour in the negative condition between the two groups of subjects can shed a light on this aspect of the processing as well. In our first study, we have found that normal adult readers benefit from being presented with the visual representation of the negated information (i.e., the mentioned argument), which is actively exploited during the real-time comprehension of negative sentences. In addition, the visual prominence of the mentioned argument has been found to have a facilitating effect on negative sentence processing: indeed, participants' looking pattern behaviour showed that negation was integrated faster into sentence meaning as the number of pictures of the mentioned argument increased. If dyslexics adopt the same non-incremental strategies of negation processing as normal adult readers, we are expecting them to replicate this pattern of fixations.

These research questions will be addressed in detail in chapter 6, which will be dedicated to our eye-tracking study on the online processing of sentential negation in Italian dyslexic adults.

6 The online processing of sentential negation in Italian dyslexic adults

This second experimental chapter is organized as follows. In §6.1 we will outline the experimental design of this follow-up study, which constitutes a reduced version of our main experiment in Chapter 4. In §6.2, we will describe the materials and the experimental procedure. In addition, we will state our predictions with respect to the two main research questions outlined in §5.4. Section 6.3 will be devoted to an in-depth analysis of both the behavioural and the eye movement data collected: the latter will be treated separately for each item type (i.e. cartoons, black and white, and coloured geometric shapes. In §6.4, we will address the theoretical implications of our findings, and we will discuss the contribution of the present research to the investigation of negation processing in developmental dyslexia. Section 6.5 will finally conclude, by restating our research questions and summarizing the answers provided.

6.1 The current study

The aim of this study is two-fold: first, investigating whether adults with dyslexia adopt the same strategy in the processing of negative sentences as control subjects; second, verifying if sentential negation constitutes a specific source of processing difficulty for dyslexics, or if they are affected by a more general processing impairment.

To this end, we administered the same task used in Study 1 (§4) to Italian speaking adults with and without a diagnosis of developmental dyslexia. Participants heard affirmative and negative sentences (1) while presented with a visual scene containing four sets of pictures, and they were asked to identify the visual referent of the verbal description. During the task, their eye movements were recorded.

(1) Aladdin is/is not closing the door and Jasmine is cuddling a tiger

The visual scene included at least one picture representing the described state of affairs and one visual competitor: for negative sentences, the visual competitor corresponded to the representation of the argument of negation (i.e., the mentioned argument). The visual prominence of the picture of mentioned argument (e.g., Aladdin closing the door in (1)) was manipulated by parametrically varying the number of quadrants in which it appears from one to three (Figure 6.1). Significantly, within the same visual scene, the mentioned argument could be either the target or the competitor depending on the polarity of the experimental sentence:

if the sentence is affirmative (e.g., *Aladdin is closing the door*), it is the target; if the sentence is negative (e.g., *Aladdin is not closing the door*), it is the picture to avoid, as it represents the negated state of affairs. It follows that, as the number of pictures of the mentioned argument increases, the number of potential targets increases in the affirmative condition, but it decreases in the negative one.

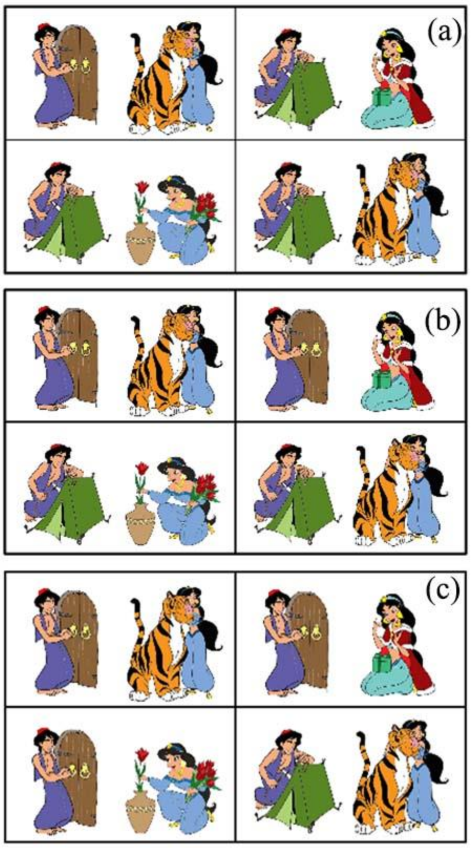

Figure 6.1. Example of visual scenario with one (a), two (b), and three (c) quadrants including the visual representation of the mentioned argument for the sentences *Aladdin is closing the door* (AFF) and *Aladdin is not closing the door* (NEG) - (i.e., Aladdin closing the door). The visual scenario in (a) includes 1 target for AFF and 3 potential targets for NEG. The visual scenario in (b) includes 2 potential targets for both AFF and NEG. The visual scenario in (c) includes 3 potential targets for AFF and 1 target for NEG.

The manipulation of the visual prominence of the mentioned argument[103] created an initial ambiguity in the reference resolution task: as shown in Figure 6.1, upon hearing the main clause *Aladdin is/is not closing door*, the visual scene could in fact include more potential visual referents of the verbal description. This temporary ambiguity allowed us to investigate how participants exploited the visual information, in particular the picture of the mentioned argument, during the real-

[103] The interested reader can refer to section §4.1 for a more comprehensive explanation of the visual manipulation introduced in the study.

time interpretation of affirmative and negative sentences. A disambiguating clause (e.g., *and Jasmine is cuddling a tiger*) was introduced for reasons of task felicity, as it provided participants with a univocal visual referent of the verbal description to successfully accomplish the task across all the experimental conditions. For the aim of the present study, we were mainly interested in the processing of the main clause, which was the one manipulated in terms of polarity: from now on, we will refer to this clause as target sentence.

As in Study 1, we included three different types of visual and linguistic stimuli (§6.2.2.2): cartoon characters with declarative sentences denoting performed actions (e.g., *Aladdin is/is not closing the door*), coloured geometric shapes with declarative sentences describing perceptual properties (e.g., *the circle is/is not red*), and black and white geometric shapes with declarative sentences expressing existential properties of the described entities (e.g., *there is/is not a square*). This allowed us to investigate whether the complexity of the visual and linguistic information might affect the online construction of the negative meaning, and, if so, to what extent. A series of behavioural tests to assess participants' reading abilities and working memory capacity were also included in the experimental protocol for this follow-up study.

6.2 Methods

6.2.1 Participants

The study was carried out 25 participants divided in two groups: the target group was composed by 9 Italian adults with dyslexia, aged 18;1-27;1(M = 23;5, *SD* = 3;45); the control group was formed by 16 adults without dyslexia, aged 20;9-29;0 (M = 25;4, *SD* = 2;65). At the moment of testing, participants in the target group were diagnosed with dyslexia on standard criteria (ICD-10; World Health Organization, 2004), and they had no diagnosed or reported oral language problems and no hearing disorders. They were recruited through the Inclusion and Accessibility Unit of the University of Verona, the Italian Association for Dyslexia AID (*Associazione Italiana Dislessia*), and announcements on the web pages of the University of Verona. Control participants were recruited at the University of Verona via an online subject pool. None of them had reported history of speech, hearing or language disorders.

All the 25 participants were volunteers and native speakers of Italian[104]. They had normal or corrected to normal vision. The participants' recruitment and testing have been interrupted due to the Covid-19 outbreak in Italy and to the related

[104] Participants have been exposed to at least one foreign language (usually English) during their studies, and they cannot therefore be considered as monolingual speakers of Italian.

situation of public health emergency occurred during the year 2020. The study was approved by the local ethics committee and conducted in accordance with the standards specified in the 2013 Declaration of Helsinki.

6.2.2 Materials

6.2.2.1 Behavioural assessment materials

Assessment of reading abilities

Participants' reading abilities were assessed through the administration of a subset of the tests proposed for the diagnosis of dyslexia in young Italian adults into the *LSC-SUA Batteria per la valutazione dei DSA e altri disturbi in studenti universitari e adulti* (Montesano, Valenti and Cornoldi 2020). The battery is designed specifically for adults and consists of 17 tasks for the investigation of four broad domains of competence: reading, writing, text comprehension, and calculation. In addition, it also includes a questionnaire to measure self-assessment of reading and spelling related difficulties that could be seen as markers for dyslexia, adapted and translated into Italian from *The revised Adult Dyslexia Checklist* (ADCL; Vinegrad 1994). The tasks consisted of two tests of reading decoding (words and non-words reading) and a *lexical decision task under articulatory suppression*. All the tasks included in the assessment of reading abilities showed a good discriminatory power, with an overall 94% of probability of correctly discriminating a university student with dyslexia from an age-matched university student without dyslexia (Re et al. 2011).

Words reading test. Participants were asked to read aloud four series of isolated words as quickly and accurately as possible. The four lists of words varied in frequency and concreteness, ranging from very common and concrete words (e.g., *treno*[105] 'train') to less frequent and more abstract ones (e.g., *tragicità*[106] 'tragedy'). For the assessment, the evaluation of subjects' reading ability included both speed and accuracy measures: the former was calculated in number of syllables read per second, while the latter in number of words read inaccurately. As for scoring, the error rate was calculated by assigning 1 point to each word read incorrectly or omitted. Self-corrections and hesitations were not considered an error as they already negatively affected the reading speed parameter. Accuracy and reading

[105] word frequency 194,290 (itTenTen16 Corpus).
[106] word frequency 2,991 (itTenTen16 Corpus).

speed raw scores were converted to z-scores[107] according to standard reference data and used for the inclusion criteria. This task obtained an overall score of 92% of discriminatory probability: words accuracy 88% and words syllable/s 96%, respectively (Re et al. 2011).

Non-words reading test. Participants were asked to read aloud two series of isolated non-words. The two lists varied in length and complexity: the *short non-words* consisted in two- or three-syllable non-words (e.g., *via-ca*), while the *long non-words* consisted in four- or five-syllable non-words (e.g., *nu-cor-pia-co*). Again, both reading speed (number of syllables read in one second), and accuracy (number of words read incorrectly) were measured by the experimenter. The scoring system was the same adopted for the previous reading task. Accuracy and reading speed z-scores were computed and used for inclusion criteria. The *non-words reading* tests represented an extremely effective task for assessing the reader's decoding ability, as it obtained an overall score of 94% of discriminatory probability: non-words accuracy 96% and non-words syllable/s 92%, respectively (Re et al. 2011). In fact, as dyslexics are well known to resort to their lexical knowledge as a source of help in the decoding of written text, the lack of any lexical cues makes non-words reading extremely demanding.

Lexical decision task under articulatory suppression In this task, participants were presented with a list of 24 words and 24 non-words mixed altogether. They had to silently read the list as fast as possible, and indicate with a stroke of a pen which words really existed. In addition, they were asked to repeat at the same time the syllable *la* continuously and aloud. Participants were given a limit of 60 seconds for task completion. For the assessment, the following parameters were taken into account: the errors (i.e., non-words marked as words), and the final score, calculated by subtracting the number of errors from the total number of words correctly identified by the subject. Raw error and final scores were converted to z-scores and used for the inclusion criteria. Similar to the previous tests, the *lexical decision task under articulatory suppression* is very reliable for discriminating dyslexic adults from non-dyslexic ones, with a very high probability-based effect size (99%, Re et al. 2011). In fact, the simultaneous repetition of the syllable *la* prevents the subject from resorting to the so-called *articulatory loop*, a working memory component which is crucially involved during writing and reading, especially at the early stages of their acquisition (Murray 1967; 1968; Baddeley & Hitch 1974; Baddeley et al. 1984, see §5.2). If the resort to the *articulatory loop* is progressively reduced as the learner masters these skills, it remains instead relatively constant in dyslexic

[107] Z-scores are measures of an observation's variability in terms of its distance from the mean. They are measured in standard deviation units (*SDs*) and can be either positive or negative depending on whether their value lies above or below the mean.

subjects (Ziegler et al. 2003, Carroll & Snowling 2004, among others). While carrying out this lexical decision task, the dyslexics' reading ability is expected to significantly deteriorate: not only can they not benefit from the *articulatory loop,* but its activation also represents a source of phonological interference.

Assessment of Working Memory Capacity (WMC)

Participants' working memory capacity was assessed through the administration of the *Digit Span Forward* and the *Digit Span Backward* tasks (standardization by Monaco, Costa, Caltagirone & Carlesimo 2013).

In the *Digit Span Forward* task (DSF), the examiner pronounced a list of digits at a rate of approximately one digit per second. After listening to the entire list, participants were asked to immediately repeat the digits in the same order. If they succeeded, the experimenter would proceed with a list one digit longer. Instead, if they did not recall the list correctly, the experimenter would present another list of the same length. The sequences of digits had an increasing length, ranging from three to a maximum of nine items, and two sequences for each length were included. The test ended when the subject failed to recall the second list with the same length. The span was determined as the length of the longest list recalled correctly, indicating the quantity of material which could be stored in the subject's short-term memory without exceeding its capacity. For what concerned the scoring, the span was calculated by assigning 1 point for each list correctly recalled, whereas no points were given for wrong repetitions.

The same procedure and scoring system were used for the *Digit Span Backward* task (DSB), except that, in this version of the test, participants were asked to repeat the list of digits in the reverse order, starting from the last digit heard and ending with the first one.

These two tests are frequently used to evaluate the verbal short-term memory, as well as Central Executive resources. Following Baddeley's influential model (1986, see §5.2.1), the DSF task mainly involves the phonological component of the Working Memory, which is devoted to the short-term maintenance of the verbal information without any further mental manipulation of the stored data. Conversely, in the DSB, the stored information must not only be maintained but also manipulated in order to repeat the sequence of digits in the reverse order. Therefore, this version of the task is believed to primarily engage Central Executive resources.

6.2.2.2 Identification task with eye-recording materials

The experiment had a 2x2x3 mixed factorial design, with sentence polarity (affirmative/negative) and number of pictures of the mentioned argument (1-3) as within-subject factors, and group (dyslexic/control) as between-subject factor. The combination of the within-subject variables generated the following six experimental conditions:

Condition	Sentence polarity	MA pictures
1	Affirmative sentence	1 picture
2	Affirmative sentence	2 pictures
3	Affirmative sentence	3 pictures
4	Negative sentence	1 picture
5	Negative sentence	2 pictures
6	Negative sentence	3 pictures

This experiment is a shortened version of the main study (Chapter 4). This choice was due to the fact that the execution of a complex and long task could have posed an excessive burden for the processing and working memory resources of the participants with dyslexia, which are notoriously limited. The same materials of Study 1 were used (throughout Chapter 4.2.2)[108], but the task included only 72 experimental trials (instead of 120), equally distributed among the three different types of stimuli: 24 items for cartoon characters, 24 items for black and white geometric shapes, and 24 items for coloured geometric shapes.

Cartoon characters. The pictures consisted of four easily recognizable cartoon couples, that were introduced to the participants during the familiarization session (Aladdin and Jasmine, Bart and Lisa Simpson, Daisy and Mickey Mouse, Donald Duck and Minnie). In all the pictures, the two characters were always performing two different actions involving common objects (e.g., eating a sandwich, combing the hair). The position of the character performing the target action was balanced across items.

Experimental sentences were Italian declarative sentences denoting performed actions, such as *Aladdin is/is not closing the door and Jasmine is cuddling a tiger*. For cartoon items, half of the sentences were affirmative, and half negative. The manipulation of sentence polarity affected only the main clause: the coordinate clause was in fact introduced only for task felicity, as it provided a visual referent for the sentence across all the experimental conditions. Experimental sentences in both affirmative and negative polarity could appear with three types of visual context, in which the number of pictures of the mentioned argument (e.g., Aladdin closing the door) parametrically varied from one to three. Within the same visual scenario, the picture of the mentioned argument could be either the target or the

[108] The reader can refer to section 4.2.2 for a more detailed explanation of how the experimental conditions and the different item types have been balanced in our experimental design.

competitor depending on the polarity of the target sentence. An example of experimental conditions for a cartoon item is reported in Figure 6.1, page 244.

Coloured geometric shapes. The pictures consisted of three coloured geometric shapes each – a square, a triangle, and a circle. Each geometric shape could only appear in two specific colours: for instance, the square could be either black or grey, the triangle either yellow or green, and the circle either red or blue. It was never the case that a triangle and a circle were both coloured in red within the same visual scene. The position of the geometric shape mentioned in the target sentence was balanced across items.

Experimental sentences were Italian declarative sentences with copulative predicates describing perceptual properties, such as *The circle is/is not red, and the triangle is green*. For coloured geometric shape items, half of the sentences were affirmative, and half negative. Similar to cartoon items, the manipulation of sentence polarity affected only the main clause, as the coordinate clause was introduced for reasons of task felicity. Experimental sentences could be matched with visual contexts in which the number of pictures of the mentioned argument (e.g., the red circle) parametrically varied from one to three. Based on sentence polarity, the mentioned argument could be either the target picture or the competitor within the same visual scene. An example of experimental conditions for a coloured geometric shape item is reported in Figure 4.3, page 155.

Black and white geometric shapes. The pictures consisted of two black and white geometric shapes each among the following: a square, a circle, a triangle, a pentagon, and a star. The position of the geometric shape mentioned in the target sentence was balanced across items.

Experimental sentences were Italian declarative sentences expressing existential properties of the described entities, such as *There is/is not a square and/but a triangle*. Half of the sentences were negative, and the other half were affirmative. Similar to the other item types, the manipulation of sentence polarity concerned only the main clause, as the subordinate/coordinate clause was only introduced for task felicity. Experimental sentences in both polarities were paired with a visual context in which the number of pictures of the mentioned argument (e.g., the square) could vary from one to three. The mentioned argument could correspond either to the target picture or to the competitor depending on sentence polarity. An example of experimental conditions for a black and white geometric shape item is reported in Figure 4.4, page 157.

6.2.3 General procedure

The study consisted of two separate sessions. The first session consisted in the administration of the behavioural tests (§6.2.2.1) to assess participants' reading abilities and working memory capacity. The second session consisted in the administration of the identification task with eye recording (§6.2.2.2) to investigate participants' online comprehension of negative sentences.

Each participant was tested individually in a soundproof room at the Laboratory of Text, Language and Cognition (LaTeC) of the University of Verona. The first session lasted approximately 20 minutes for each participant, whereas the second session approximately 40 minutes. The two sessions were usually performed on the same day, with an intermediate break of approximately 15 minutes. The entire experimental session lasted approximately 1 hour and 30 minutes for each participant.

Identification task with eye recording procedure. The experiment was conducted using an SR Research EyeLink 1000 Plus head-mounted eye tracker, and participants' eye movements were recorded at a rate of 1000Hz. Participants were calibrated at the beginning of the experiment using a nine-point display. Calibration and validation procedures were repeated multiple times throughout the experimental session.

The same procedure of Study 1 (§4.2.3) was adopted. Before the beginning of the experimental session, participants were informed that they would listen to a series of sentences while some pictures would be displayed in the four quadrants of the screen. Their task was to find the visual referent of the verbal description and press space bar upon identification. To choose the correct picture, they simply had to keep looking at the corresponding quadrant while pressing the button for confirmation. Participants were informed that, although there was no time limit for choosing a picture, it was important to accomplish the task as quickly and accurately as possible. They were also asked to stay seated as still as possible throughout the duration of the test.

The experimental session was preceded by a practice and a familiarization block. The practice session was useful for the participants to familiarize with the task, and to make sure that they had correctly understood the instructions. During the familiarization block, participants were introduced to the four cartoon couples employed in the experimental items: this allowed participants to recall the names of the different cartoon characters so as to carry out the identification task properly.

Trials started with a one-second presentation of a central fixation cross. Following a two-second preview of the visual scenario, participants were auditorily presented with the experimental sentence. After the sentence onset, the visual scene remained displayed on the screen until participants pressed the space bar. If the space bar was pressed during the presentation of the audio stimulus, this did not affect the task execution. The trial concluded with the appearance of the written instruction *Press space bar to continue*: this allowed participants to manage the pace of the task execution and to avoid possible mental fatigue. No response-contingent feedback was provided during the test.

The 72 experimental items were presented in 2 blocks of 36 items each: at the end of the first block, dyslexic participants were required to take a break for at least five minutes. After the break, the calibration procedure was repeated. At the end of the experimental session, participants were informed on the goal of the research. An example of one experimental trial is shown in Figure 4.5, page 160.

6.2.4 Predictions

The manipulation of the visual prominence of the mentioned argument allowed us to investigate whether it was the activation or the inhibition of the negated information which hindered the processing costs of a negative sentence such as *Aladdin is not closing the door* compared to the corresponding affirmative. In our first study, we reported compelling evidence that the processing costs traditionally attributed to negative sentences are determined by the need to retrieve the negated information, which must be activated and then subsequently inhibited in order to interpret the negative sentence meaning. In line with a non-incremental view of negation processing, control subjects benefited from being presented with the visual representation of the negated information (i.e., the mentioned argument), which was actively exploited during the real-time comprehension of negative sentences.

Previous studies on negation processing and dyslexia (Vender & Delfitto 2010, Scappini et al. 2015, Hu et al. 2018, see §5.4) have argued that the interpretative difficulties exhibited by dyslexics with negative sentences are rooted in the high computational demand of the non-incremental processing of negation, which requires the retrieval/construction of the mental representation of the negated information and its temporary maintenance in the short-term memory for its subsequent comparison with the simulation of the actual state of affairs (Kaup et al. 2007, see §2.2.1.3). This would result in an overload of the limited working memory resources of the dyslexic subjects, preventing them from successfully interpreting negative sentences, either because they cannot cope with the task (Vender & Delfitto 2010) or because they need to resort to alternative but less efficient processing strategies (Scappini et al. 2015).

In light of the above, we predicted a facilitating effect of the visual prominence of the mentioned argument on the interpretation process for dyslexics. The prominence of the negated information in the visual scene would in fact make significantly easier the retrieval/activation and the maintenance of the negated information in the working memory, reducing the overload of dyslexics' limited computational resources. In terms of looking pattern behaviour, we were expecting to find a similar pattern of fixations with negative sentences in the control and the dyslexic group, replicating the pattern of findings reported in the first experiment: that is, a *reduced penalty* for target identification, compared to the affirmative baseline, as the number of pictures of the mentioned argument (corresponding to the negated information) increased.

Based on previous findings, we expected dyslexics to adopt the same non-incremental strategy of negation processing as controls, and thus benefit from the visual prominence of the negated information. However, it could be the case that negation processing is not specifically impaired in individuals with developmental dyslexia, who might suffer from more generalized interpretative difficulties with both affirmative and negative sentences (Scappini et al. 2015, Hu et al. 2018). If negation constituted a specific source of processing impairment for dyslexics, two possible outcomes would be expected:

i) A control-like performance with both affirmative and negative sentences. If their processing difficulties were completely attributable to the high computational demand of a non-incremental computation of negation (cf. Vender & Delfitto 2010), we would expect no delay in target identification with negative sentences compared to controls: in fact, the visual prominence of the negated information would significantly reduce the working memory load required for the computation.

ii) A performance worse than controls' only with negative sentences. It could also be the case that dyslexics' interpretative difficulties with negative sentences were only partially related to the high computational costs of a non-incremental processing of negation. If so, we would expect dyslexics to underperform in target identification with negative sentences compared to controls.

Otherwise, if dyslexics were affected by a more general processing impairment (cf. Scappini et al. 2015, Hu et al. 2018), we would expect an overall delay in target identification compared to controls with both affirmative and negative sentences.

6.3 Results

6.3.1 Behavioural assessment

In order to be included in the study, participants diagnosed with dyslexia had to score 1.5 standard deviations (*SDs*) below the mean of the normative data for their age group in at least two measures of the reading tasks (either accuracy or speed) and in one measure of the lexical decision task under articulatory suppression (either errors or final score). All the subjects initially recruited for the dyslexic group were included in the analysis as they all performed below the pathologic performance cut-off in at least three measures of the reading assessment. Conversely, controls had to score within the normal ranges in all the reading tasks. The performance of 15 out of 16 subjects recruited in the control group was included in the analysis, as one subject performed 2.46 *SDs* below the mean in one of the measures (final score) of the lexical decision task under articulatory suppression.

Reading abilities. A series of independent sample t-tests were conducted to compare the performance of the two groups in each measure of the three reading tasks. Relevant data and statistical significance of the t-tests are reported below in Table 6.1.

As for words reading, results showed that dyslexics were significantly slower [$t(22) = -6.44$, $p < .001$] and less accurate [$t(22) = 4.07$, $p < .001$] than controls. Similar results were obtained for what concerned non-words reading: dyslexic participants experienced significantly greater difficulties in comparison with control subjects in both accuracy [$t(22) = 3.81$, $p < .001$] and reading speed [$t(22) = -6.09$, $p < .001$]. Finally, dyslexics performed significantly worse than controls also in the lexical decision under articulatory suppression task, in which they were less accurate [$t(22) = 3.01$, $p < .01$] and obtained lower final scores [$t(22) = -4.74$, $p < .001$].

Task	**Controls** (=15)	**Dyslexics** (=9)	**t(22)**	***p-value***
Words reading – speed mean and (SD)	4.92 (0.83)	2.77 (0.72)	-6.44	< .001
Words reading – accuracy mean and (SD)	1.13 (1.06)	3.89 (2.26)	4.07	< .001
Non-words reading – speed mean and (SD)	3.15 (0.64)	1.77 (0.25)	-6.09	< .001
Non-words reading – accuracy mean and (SD)	2.07 (1.28)	5.33 (2.92)	3.81	< .001
Articulatory suppression – errors mean and (SD)	0.47 (0.74)	1.67 (1.22)	3.01	< .01
Articulatory suppression – score mean and (SD)	45.30 (8.48)	24.89 (12.70)	-4.74	< .001

Table 6.1. Mean scores (standard deviations) of dyslexics and controls in the reading tasks and independent sample t-tests results.

Working Memory capacity. Independent sample t-tests revealed significant group differences in the short-term working memory. Dyslexics performed worse than control subjects by recalling shorter lists of digits in both the Digit Span Forward [$t(22) = -2.15$, $p = .043$] and the Digit Span Backward [$t(22) = -2.35$, $p = .027$] tasks. These results suggest significant phonological (DSF) and central executive (DSB) impairments in adult dyslexics. Relevant data and statistical significance of the t-tests are reported below in Table 6.2.

Task	**Controls** (=15)	**Dyslexics** (=9)	**t(22)**	***p-value***
Digit Span Forward (DSF)	6.67 (0.97)	5.89 (0.60)	-2.15	.043
Digit Span Backward (DSB)	5.67 (0.90)	4.56 (1.42)	-2.35	.027

Table 6.2. Mean scores (standard deviations) of dyslexics and controls in the working memory tasks and independent sample t-tests results.

6.3.2 Identification task with eye-recording: behavioural data

Behavioural data concern the acceptance rate of the target picture at the end of each trial. The aim of the behavioural analyses was to assess participants' final sentence comprehension, and to make sure that participants had been actively involved in task execution. Moreover, we were interested in possible group differences in response accuracy.

Table 6.3 shows the average accuracy in target identification for affirmative and negative sentences across item types for both groups. At first glance, it seems that dyslexics were generally less accurate than controls except for the negative condition with cartoon characters. Moreover, both groups displayed a lower accuracy with black and white geometric shapes in both affirmative and negative conditions compared to the other item types.

We calculated a mixed-effects logistic regression model with response accuracy (correct vs. incorrect) as dependent variable, and *item type* (cartoon, black and white, and coloured geometric shapes), *polarity* (AFF vs. NEG) and *group* (dyslexics vs. controls) as independent variables. Participants and items were added as crossed random effects (random intercepts). Random slopes for participants and items were included if this improved the fit of the model (as estimated by comparing the logLikelihoods of the models using the anova-function in R). Non-significant interactions were removed from the model. Although dyslexics were overall less accurate than controls in target identification (65% vs. 69%, respectively), the lack of a main effect of *group* ($x2 = 0.17$, df = 1, $p = .680$) revealed that this behavioural difference did not yield statistical significance. Nonetheless, it indicates an interesting tendency that might find confirmation in a future implementation of the experiment with an increase in the number of subjects tested. Furthermore, the lack of *group* × *polarity*, *group* × *itemtype*, and *polarity* × *itemtype* × *group* interactions indicates that the performance of the two groups was not modulated by the type of the linguistic stimuli provided, neither by sentence polarity nor by their interaction. The lack of a main effect of *polarity* (x2= 3.12, df = 1, *p* = .627) reveals that participants' final choices were not affected by the polarity of the sentence: on average, they correctly identified the visual referent of the verbal description 68% of the time when presented with affirmative sentences, and 66% of the time when presented with the negatives. The analysis yielded a significant main effect of *item type* (x2= 13.37, df = 2, *p* < .001). Post-hoc comparisons with Tukey correction of p-values (emmeans()-function in R) showed that the accuracy in target identification differed significantly between black and white geometric shapes and coloured geometric shapes (63% vs. 71%, respectively, *ß* = 0.54, SE = 0.15, z = 3.65, *p* < .001), whereas no significant differences were reported between black and white geometric shapes and cartoon characters (63% and 67%, respectively, *ß* = 0.28, SE = 0.15, z = 1.97, *p* = .120) and between cartoon characters and coloured geometric shapes (67% and 71%, respectively, *ß* = 0.25, SE = 0.15, z = 1.71, *p* = .203). To conclude, the lack of a *polarity* × *itemtype* interaction reveals that the accuracy in target identification among item types was not modulated by sentence polarity.

		Accuracy	
Polarity	**Item Type**	**Dyslexics**	**Controls**
AFF	Black and white geom. shapes	.60	.66
	Cartoon characters	.69	.72
	Coloured geom. shapes	.65	.75
NEG	Black and white geom. shapes	.60	.63
	Cartoon characters	.66	.63
	Coloured geom. shapes	.70	.72

Table 6.3. Average accuracy in target identification for affirmative and negative sentences across item types for the dyslexic and the control groups

Taken together, these results indicate that both groups have understood the task correctly, and that the participants' final choices were not affected by sentence polarity. Although the average accuracy was not very high (65% for dyslexics and 69% for controls, respectively), this result is consistent with what reported in Study 1 (§4.3.1), where participants' accuracy rate was 68%. As already underlined for

Study 1, the fact that the average accuracy did not exceed 70% can be explained by possible experimental artefacts: first, participants might be looking either at the space bar while pressing it or elsewhere on the screen instead of looking at the quadrant, as specified in the instructions; second, although there was no time limit for choosing a picture, participants might be committed to the experiment and tried to answer faster at the expense of accuracy. Unlike in Study 1 (Chapter 4), results showed that the accuracy in target identification was modulated by the type of linguistic stimuli provided, with participants being less accurate in target identification when presented with black and white geometric shapes. Significant group differences in task execution were not reported, although a tendency can be observed, with dyslexic adults being overall less accurate than normal readers.

In the following sections, we will examine the results coming from the online data with the aim of disentangling possible effects of polarity and visual prominence of the mentioned argument on the real-time sentence processing.

6.3.3 Identification task with eye-recording: eye movement data

The computation of the eye-movement data generated by the EyeLink system was performed through an open-source Python-based visual world experiment analysis. The statistical analyses were conducted using the LmerTest Package (Kuznetsova et al. 2017) for the R platform. As in Study 1, the time period analysed was from the onset of the critical word (Disambiguation Point – DisP) to 2000ms after its onset: crucially, the DisP allowed participants to identify the potential visual referents of the verbal description for both affirmative and negative sentences, and it corresponded to the onset of the mentioned argument (2-4).

(2) Aladdin is/is not [DisP] closing…
(3) The triangle is/ is not [DisP] green…
(4) There is/is not [DisP] a pentagon…

The two-second time period was chosen to guarantee that there was enough time to comprehend negation (Kaup et al. 2006, Lüdtke et al. 2008, Orenes et al. 2014, 2015). Within this time period, we identified as major area of interest the time-window from the offset of the critical word (650ms) to 1500ms after its offset (2150ms). The time-window is 500ms wider than that analysed in Study 1: this choice was made on the basis of previous literature showing that dyslexics have greater difficulties than controls in sentence comprehension, which might result in higher error rates (Vender and Delfitto 2010) and/or slower response times (Scappini et al. 2015, Hu et al. 2018 for poor readers, see §5.3). This 1500ms time-window allowed us to investigate and compare the time course of sentence comprehension in the two groups of subjects. The length and the onset of this broad time-window have been matched across items and conditions.

The same eye-movement analyses of Study 1 were conducted. The descriptive analyses (one on the target and one on the mentioned argument) were useful to visually explore the time course of sentence interpretation by subdividing the time period of interest in 50ms time-slots. The statistical analysis confirmed possible patterns of fixations emerged in the exploratory descriptive analysis on the target in our major area of interest.

In the descriptive analysis on the target, the graphs show the value of target preference for the selected time period computed in 50ms time-slots. The target preference corresponds to the time spent fixating the target (i.e., the visual referent of the verbal description in (2-4)) as a proportion of total time spent in fixating both the target and the competitor. Note that, for negative sentences, the visual competitor corresponded to the mentioned argument. If the target preference equals 1, it means that every participant in every trial was looking at the target during the whole time slot. If it equals 0, it means that they were looking at the competitor. Values between 1 and 0 indicate that some participants were looking at the target whereas others were looking at the competitor. Significantly, we considered as target fixations those towards all the possible visual referents of the target sentence: if, for instance, the visual scenario included two potential targets for the sentence *The triangle is green*…, we considered as fixations towards the target the fixations towards both the pictures of a green triangle. As a consequence, the baseline for target preference differed across experimental conditions including a different number of potential targets. In the abovementioned condition with two target pictures, the baseline for target preference was .50 (two out of four pictures): if the target preference equals .50 (chance level) it means that there is maximum uncertainty as to whether the target or the distractor is the referent of the verbal description. As the line departs from .50, a preference towards the target (> .50) or the distractor (< .50) has been made. In the condition with only one potential target, the baseline for target preference was .25 (one out of four pictures), whereas in the condition with three potential targets, it was .75 (three out of four pictures).

In the descriptive analysis on the mentioned argument, the graphs show instead the value of the Mentioned Argument (MA) preference for the selected time period computed in 50ms time-slots. The MA preference corresponds to the time spent fixating the mentioned argument as a proportion of a total time spent in fixating both the mentioned argument and the competitor. As in the previous analysis, we considered as MA fixations those towards all the pictures of the mentioned argument depicted in the visual scenario: if, for instance, the visual scenario included two pictures of a green triangle for the sentence *The triangle is not green…*, we considered as fixations towards the mentioned argument the fixations towards both the pictures of a green triangle. Again, the baseline for MA preference differed across experimental conditions including a different number of MA pictures: .25 in the condition with one mentioned argument; .50 in the condition with two mentioned arguments; .75 in the condition with three mentioned arguments. Note that the picture of the mentioned argument corresponded to the visual referent of the verbal description in the case of affirmative sentences; instead, it represented the competitor in the case of the negative ones, as it corresponded to the visual representation of the negated state of affairs.

In the statistical analysis, the target preference, computed over the time-window identified as our major area of interest (650ms-2150ms), was investigated across experimental conditions including one, two, and three potential targets. The main goal of this analysis was to provide statistical confirmation of possible effects of the visual prominence of the mentioned argument on target identification in the negative condition compared to the affirmative baseline.

The three types of stimuli employed in the task (i.e., cartoon characters, coloured, and black and white geometric shapes) corresponded to three different experimental conditions, and will therefore be analysed separately in the following sections. For each type of stimuli, we will first present the exploratory results from the descriptive analysis on the target by comparing the looking pattern behaviour of the two groups of participants during the time course of sentence interpretation in each experimental condition. Then, we will illustrate the target preference analysis computed over our broad time-window of interest across experimental conditions including a different number of potential targets. Finally, we will visually explore the results of the descriptive analysis on the mentioned argument to understand whether, and to what extent, participants exploited the visual representation of the negated information during real-time sentence comprehension.

6.3.3.1 Cartoon characters

Descriptive analysis on the target

One potential target. The graphs in Figure 6.2 depict the proportion of looks to the target after the Disambiguation Point (5), computed in 50ms time-slots, for controls (a) and dyslexics (b) in the experimental conditions including one potential target. The affirmative condition (AFF) is plotted in blue, and the negative condition (NEG) is plotted in red. The horizontal axis shows the selected time period, and time point 0-ms corresponds to DisP onset. Vertical lines are drawn accordingly to the time-window identified as our major area of interest (650ms-2150ms), and used in the statistical analysis below. In this condition, the base probability of target fixation is .25, as there is only one possible referent of the verbal description among the four pictures displayed in the visual scene.

(5) Aladdin is/is not [DisP] closing the door…

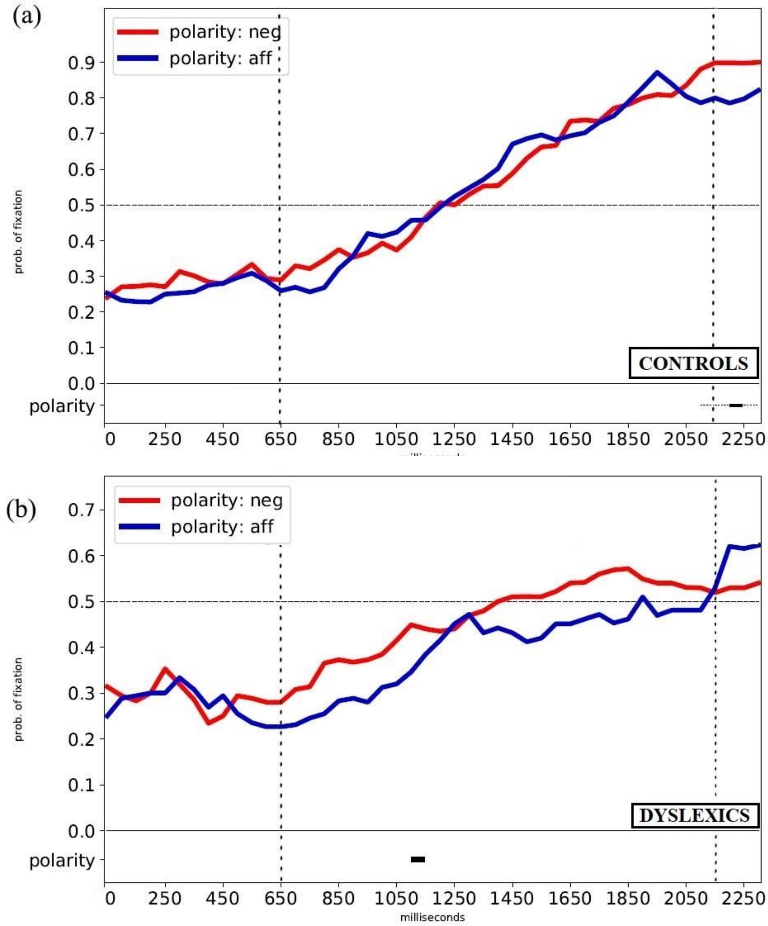

Figure 6.2. Proportion of looks to the target for AFF (blue) and NEG (red) sentences in the condition with one potential target for controls (a) and dyslexics (b). The black segments at the bottom display the significance of the main effect of *polarity*.

For the control group, a visual inspection of graph (6.2b) shows that the target preference arose beyond the chance level (.25) within 100ms after the disambiguation offset in both the affirmative and the negative conditions. Moreover, the blue line (AFF) and the red line (NEG) almost overlap for the whole time-window between 650ms and 2150ms. All in all, this reveals that the target was disambiguated very quickly in both conditions, and that there was not difference between AFF and NEG conditions with respect to the moment in which the target is disambiguated. At the end of our broad time-window (2150ms from DisP onset), the target preference reached .80 for AFF and .90 for NEG.

We conducted a statistical analysis on the fine-grained time-windows to investigate whether sentence polarity had an influence on the target preference. A Generalized Mixed Model based on the binomial distribution (Jaeger 2008) with *item* and *subject* as random factors and *polarity* as fixed factor has been conducted in each time slot and for each condition to assess its significance. Target preference was converted into a dummy binary variable: in each trial, it was assigned a value of 1 if greater than 0.5 (i.e., more looks to the target), and of 0 if smaller than 0.5 (i.e., more looks to the competitor). The outcome of this analysis is summarized below in the graph by the presence or absence of small black horizontal segments: a dotted line indicates a quasi-significant effect of *polarity* (*p*-value between .1 and .05); a solid line indicates a significant effect ($p < .05$), whereas a bold solid segment indicates that the polarity effect was highly significant ($p < .01$). The statistical analysis attests that that the difference between AFF and NEG conditions is not significant in our area of interest (time-windows between 650ms and 2150ms), as shown by the lack of solid segments below the graph, suggesting that the target was similarly disambiguated in the two conditions (see Appendix C; Table 6.1)

For the dyslexic group, graph (6.2b) shows that the target preference arose above chance level (.25) immediately after the disambiguation offset for the NEG condition. For the AFF condition, instead, target fixations started to increase about 200ms after the offset of the disambiguation. Moreover, we notice that the red line (NEG) is above the blue line (AFF) for almost the entire broad time-window between 650ms and 2150ms, indicating that participants were looking more often at the target picture in the negative condition than in the affirmative one. However, this difference in target preference results in a significant main effect of *polarity* only in the 50ms time-slot between 1100ms and 1150ms (see Appendix C; Table 6.1). Overall, this suggests that there was no general significant advantage in target identification for the NEG condition over the AFF one, as the two conditions are not significantly different in those time-slots. Quite interestingly, at the end of our area of interest (2150ms from the DisP onset), the target preference stopped at .55 for both AFF and NEG conditions: this suggests that, at 1500ms after the offset of the disambiguation, dyslexics were looking more often at the target picture, but they are still paying attention also to the competitor (i.e., the mentioned argument).

To sum up, these results indicate that in both groups the target picture was rapidly disambiguated in both AFF and NEG conditions, and that there was not significant advantage in target identification between the two conditions. If we compare the two graphs in Figure 6.2, we can notice a more prominent increase of the target preference in the control group (a) than in the dyslexic one (b): it seems in fact that the control group displays higher target preference values in both the AFF and the NEG conditions in comparison to the dyslexic group. For instance, at 600ms after the disambiguation offset (1250ms in the graph) the target preference in both groups is about .50 for both the AFF and the NEG conditions. However, at the end of our area of interest (2150ms in the graph) the target preference in the control group has reached .80 for the AFF condition and .90 for the NEG one, whereas it amounts to .55 for both conditions in the dyslexic group. This difference in the target preference values between the two groups of participants suggests that dyslexics were looking at the target picture less steadily than controls, even after the initial increase in target fixations. Group differences will be further investigated in the statistical analysis on the target.

Two potential targets. The graphs in Figure 6.3 depict the proportion of looks to the target after the Disambiguation Point, computed in 50ms time-slots, for controls (a) and dyslexics (b) in the conditions including two potential targets. The affirmative condition (AFF) is plotted in blue, and the negative condition (NEG) is plotted in red. In this experimental condition, the base probability of target fixation is .50, as there are two possible visual referents of the verbal description out of the four pictures displayed in the visual scene.

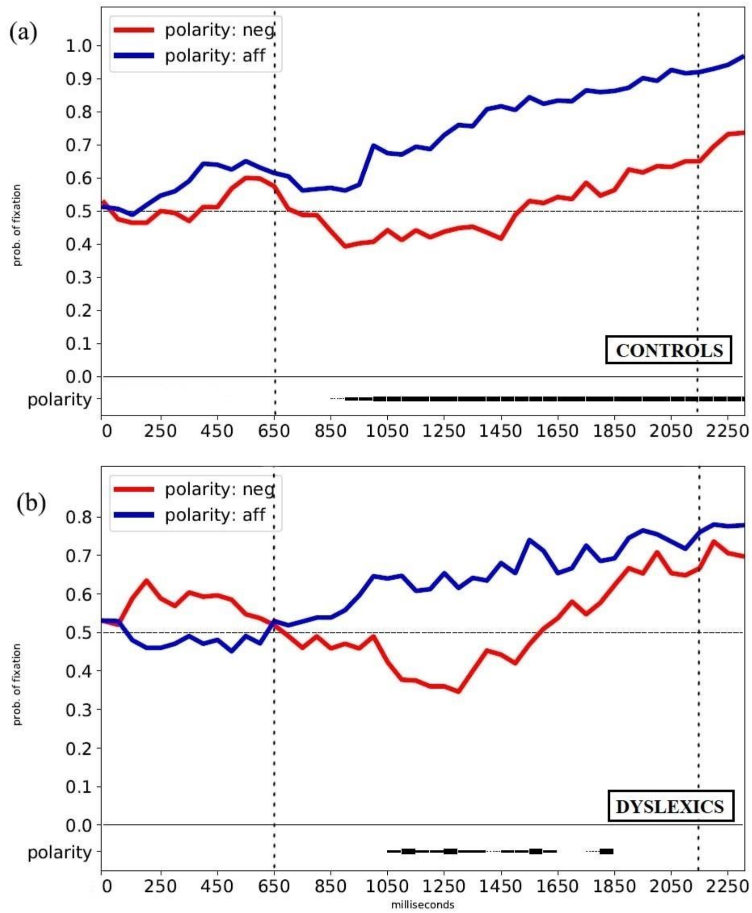

Figure 6.3. Proportion of looks to the target for AFF (blue) and NEG (red) sentences in the condition with two potential targets for controls (a) and dyslexics (b) The black segments at the bottom display the significance of the main effect of *polarity*.

For the control group, graph (6.3a) shows a rapid increase of fixations towards the target for the AFF condition, which arose above chance level (.50) about 200ms after the onset of the disambiguation. Instead, for the NEG condition, we can notice that target preference decrease after the disambiguation offset, with participants' looks converging towards the target (> .50) only 900s later (at 1550ms in the graph).

This suggests that participants were faster at identifying the target in the AFF condition than in the NEG one. In the latter, there was a greater uncertainty as to which picture (i.e., the target or the competitor) was the referent of the negative sentence, as indicated by the fact that target fixations did not exceed chance level for nearly a second from the disambiguation offset: when the line goes below .50, it means that participants were looking more often at the competitor (i.e., the mentioned argument), whereas when the line departs beyond .50, it means that a decision towards the target picture has been made. This difference between the two conditions causes target preference in the AFF condition (blue line) to be above target preference in the NEG condition (red line) during our entire area of interest (650ms-2150ms). At the end of our broad time-window, the target preference reached .90 for AFF and .70 for NEG, suggesting that, even after target disambiguation, participants were looking at the target less steadily in the NEG condition than in the AFF baseline. This results in a significant main effect of *polarity* from 250ms after the disambiguation offset (at 900ms in the graph) onwards – marginally significant in the previous 50ms time-slot (see Appendix C; Table 6.2).

A similar trend can be observed in graph (6.3b) for dyslexics: while in the AFF condition there was a rapid increase of fixations towards the target within 200ms after the disambiguation offset, in the NEG condition the target preference arose above chance level about one second later than in the AFF one (at 1650ms in the graph). In addition, the blue line (AFF) is above the red line (NEG) for the entire time-window between 650ms and 2150ms. Like in the control group, this suggests that the target was disambiguated faster in the AFF condition than in the NEG one. In the latter, after the disambiguation offset, the target preference remains at chance level for about 400ms (until 1050ms in the graph), suggesting that participants were equally long looking at the target and the competitor. At this point, we can notice a more robust decrease in target fixations in comparison to the control group, which dropped to .35 until 700ms after the disambiguation offset (at 1350ms in the graph). Here, target preference started to increase, exceeding chance level at 1650ms. This pattern of target fixations in the NEG condition seems to suggest that dyslexics were looking at the competitor (i.e., the mentioned argument) more steadily than controls before their attention converged towards the target picture. This difference in target preference between the AFF and the NEG conditions results in a main effect of *polarity* between 1050ms and 1650ms, suggesting that there was a significant advantage in target identification for the AFF condition over the NEG one (see Appendix C; Table 6.2). After the target has been disambiguated, we can observe a rather rapid increase of looks to the target in the NEG condition. The only 50ms time-slot displaying an effect of polarity is between 1850ms and 1900ms, suggesting that, from 1650ms onwards, participants were looking at the target at almost the same rate regardless of sentence polarity. At the end of our area of interest (at 2150ms in the graph), the target preference in the dyslexic group has reached .75 in the AFF condition and .65 in the NEG one.

Summarizing, the results indicate that in both groups the target is disambiguated faster in the affirmative condition than in the negative one, suggesting that both dyslexics and controls were slower at identifying the target when presented with negative sentences. If we compare the two graphs in Figure 6.3, we can observe similar patterns of fixations between the two groups in both the AFF and the NEG condition, with similar target preference values in our area of interest (650ms-2150ms). Worth noting, when presented with negative sentences, dyslexics look more often at the competitor (i.e., the mentioned argument) than controls before target disambiguation, occurring for both groups at about one second after the offset of the disambiguation.

Finally, if we compare Figure 6.2 and Figure 6.3, it seems that, in our area of interest, the difference between AFF and NEG conditions in target preference is larger in the experimental condition with two potential targets for both groups. This indicates that, despite the greater number of potential targets in the visual scenario, the NEG condition displayed a greater processing penalty in target identification compared to the affirmative baseline for both dyslexics and controls. This aspect will be further investigated with the statistical analysis on the target in the following section.

Three potential targets. The graphs in Figure 6.4 depict the proportion of looks to the target after the Disambiguation Point, computed in 50ms time-slots, for controls (a) and dyslexics (b) in the conditions including three potential targets. The affirmative condition (AFF) is plotted in blue, and the negative condition (NEG) is plotted in red. In this experimental condition, the base probability of target fixation is .75, as there are three possible visual referents of the verbal description out of the four pictures displayed in the visual scene.

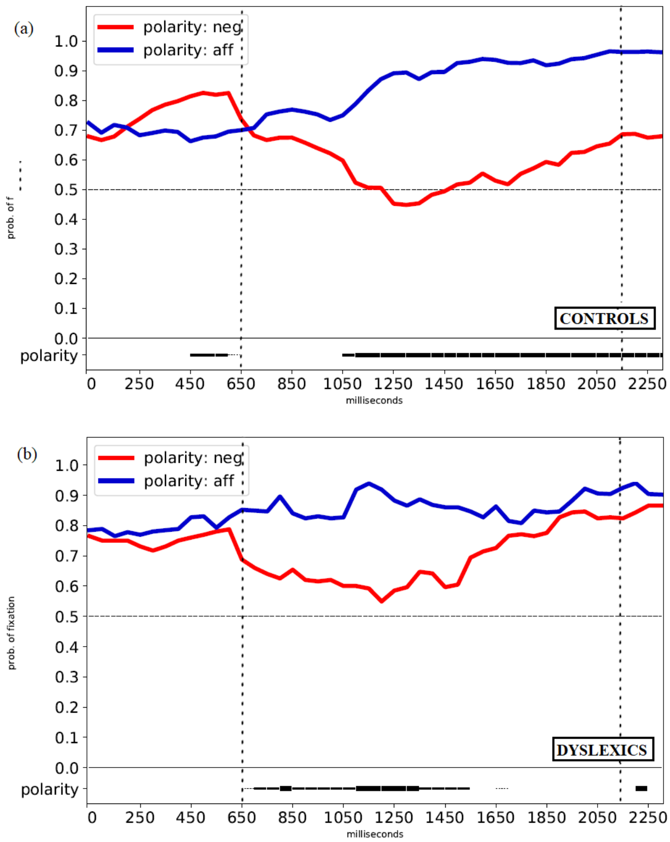

Figure 6.4. Proportion of looks to the target for AFF (blue) and NEG (red) sentences in the condition with three potential targets for controls (a) and dyslexics (b) The black segments at the bottom display the significance of the main effect of *polarity*.

For affirmative sentences, the graphs show an increase in target fixations immediately after the disambiguation offset for both controls (6.4a) and dyslexics (6.4b), with target preference reaching .95 for the former and .85 for the latter at the end of our broad time-window (at 2150ms in the graph). Instead, for negative sentences, we can observe a sudden decrease of fixations towards the target after the offset of the disambiguation in both groups, indicating that participants were looking at the picture of the competitor (i.e., the mentioned argument). In the control group, target preference dropped for about 800ms, reaching .45 at 1450ms in the graph. Here, target preference started to increase, reaching a value similar to the initial one (.70) only at the end of the broad time-window. Likewise, in the dyslexic group, target fixations decreased for about 600ms, reaching .55 at 1250ms in the graph. Then, participants' looks towards the target started to increase, reaching the initial target preference about one second after the disambiguation offset (1650ms in the graph): at the end of our area of interest, the target preference in the NEG condition is .80. This difference between affirmative and negative sentences causes target preference in the AFF condition (blue line) to be above target preference in the NEG condition (red line) from the disambiguation offset

(650ms) to the end of our broad time-window (2150ms) in both groups. The rapid decrease of target fixations in the NEG condition results in a main effect of *polarity* from 1050ms onwards for controls, and between 650ms and 1550ms for dyslexics, suggesting that the target was disambiguated faster in the AFF condition than in the NEG one (see Appendix C; Table 6.3). Moreover, the statistical analysis revealed that, after target disambiguation, controls were looking at the target picture less steadily in the NEG condition than in the AFF baseline, whereas dyslexics were looking at the target at almost the same rate regardless of sentence polarity.

Taken together, these results show a significant advantage in target identification for the AFF condition over the NEG one for both groups. Interestingly, the visual scenario with three potential targets included, for the negative condition, only one picture of the mentioned argument. Intuitively, the decrease of target fixations reported for this condition suggests that, despite the very high probability of target fixation (.75), participants' visual attention was initially drawn towards the picture corresponding to the negated information. This aspect will be explored with the descriptive analyses on the mentioned argument.

To conclude, if we compare Figure 6.3 and Figure 6.4, we can see that, in our area of interest (650ms-2150ms) the difference between AFF and NEG conditions in target preference is more pronounced in the condition with three potential targets, but, crucially, only for dyslexics. Therefore, it seems that, between the two groups of participants, dyslexics were those who displayed a greater delay in target identification in the NEG condition compared to the AFF baseline as the number of potential target increases. This processing penalty and possible group differences in target identification across conditions will be further investigated with a statistical analysis in the following section.

Statistical analysis on the target

From the previous analysis, it emerged that both groups were slower in target identification in the NEG condition compared to the AFF baseline when the visual scene included two and three potential targets. Moreover, this penalty carried by NEG was more pronounced at the increase in the number of target pictures for dyslexics, whereas it seemed unvaried for controls. Instead, no clear advantage in target identification was displayed for neither group between affirmative and negative sentences in the condition with only one target picture. In this section we seek confirmation of whether target identification is affected by sentence polarity, as well as by the interaction between sentence polarity and the number of target pictures displayed in the visual scenario. In addition, we aim to assess possible relevant group differences in the process of target identification.

Figure 6.5 illustrates the target preference computed over the broad time-window of interest (650ms-2150ms) for all participants in the experimental conditions including one, two, and three potential targets. Figure 6.6 shows the target preference for each of the two groups: (a) for controls and (b) for dyslexics, respectively. The horizontal axis shows the three experimental conditions, and the vertical axis the absolute proportion of looks to the target(s). The means for each group are reported in the table below the graphs. The AFF condition is plotted in blue, and the NEG condition is plotted in red. In this analysis, the onset of the time-window was shifted 200ms after the relevant marker in the speech stream to account for saccade programming (Allopenna et al. 1998, Matin et al. 1993).

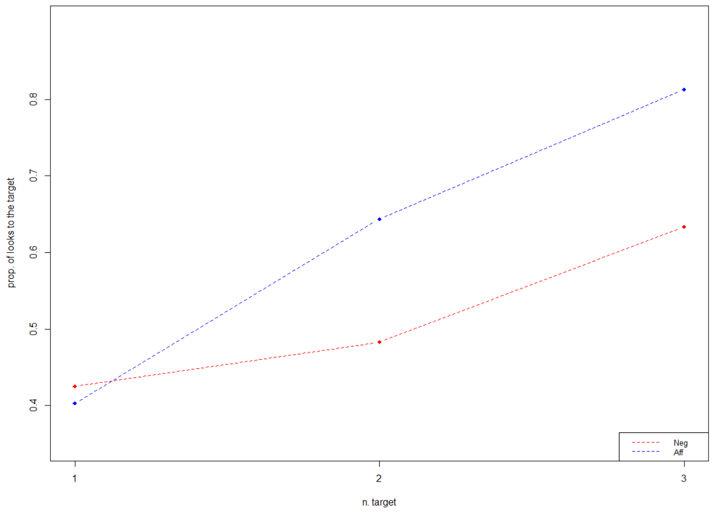

Figure 6.5. Overall proportion of looks to the target(s) in the broad time-window (650ms-2150ms) for in AFF (blue) and NEG (red) conditions including one, two, and three potential targets.

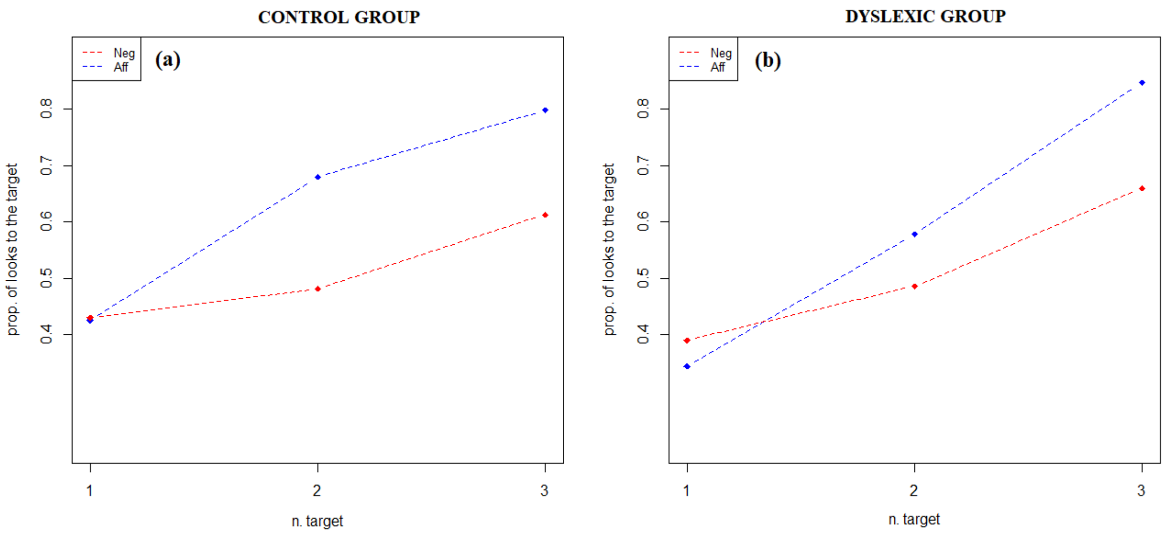

Figure 6.6. Proportion of looks to the target(s) in the broad time-window (650ms-2150ms) for the control (a) and the dyslexic (b) group in AFF (blue) and NEG (red) conditions including one, two, and three potential targets.

	Control Group		Dyslexic Group	
N. target	AFF	NEG	AFF	NEG
1	.44	.44	.35	.38
2	.68	.48	.58	.48
3	.79	.62	.85	.66

We calculated a linear-mixed effects regression model with *target preference* as dependent variable and *group* (controls vs. dyslexics), *number of targets* (1,2,3) and *polarity* (AFF vs. NEG) as independent variables using the packages lme4 and lmer Test in R (Bates et al. 2015, Kuznetsova et al. 2017). A logarithmic transformation has been applied to the target preference to make it suitable for statistical analysis (Jaeger 2008). Participants and items were added as crossed random effects (random intercepts). Random slopes for participants and items were included if this improved the fit of the model (as estimated by comparing the logLikelihoods of the models using the anova-function in R). Non-significant interactions were removed from the model.

The analysis yielded a significant main effect of *polarity* (*ß* = -0.11, t = -5.95, $p <$ 0.001), revealing that participants were looking significantly less at the target when presented with negative sentences (.51) than with the corresponding affirmative ones (.62). In addition, a significant effect of *number of targets* (*ß* = 0.30, t = 7.69, $p < 0.001$) was reported, indicating that, as can be observed in Figure 6.5, participants were looking more often at the target picture as the number of target pictures displayed in the visual scene increased. However, this effect is most probably due to the different base probability of target fixations across experimental conditions with one, two, and three potential targets (.25, .50, .75, respectively).

The lack of a *group* effect (*ß* = 0.02, t = 1.02, $p = .318$) reveals that, overall, dyslexics had a control-like performance in the reference resolution task, as indicated by very similar target preference values displayed by the two groups of participants (dyslexics .55 vs. controls .57). Moreover, the lack of a *polarity* × *group* effect reveals that the difference in target preference values between AFF and NEG conditions was similar in the control (AFF .63 vs. NEG .51) and in the dyslexic group (AFF .59 vs. NEG .51). This indicates that the performance of the two groups in target identification was not differently affected by the polarity of the sentence.

As can be observed in Figure 6.5, the difference in target preference values between AFF and NEG conditions becomes more prominent at the increase in the number of potential targets. The presence of a *polarity* × *number of targets* (*ß* = -0.10, t = -4.60, $p < .001$) interaction confirms that participants were looking at the target picture significantly less steadily when presented with NEG sentences than with the corresponding AFF baseline as the number of potential targets increased.

In the condition with one potential target, the target picture was fixated at almost the same rate in the AFF and the NEG conditions, suggesting that there was not significant advantage in target identification between the two conditions. Worth noting, the target picture was fixated slightly less often in the AFF condition than in the NEG one (.40 vs .42): this non-significant advantage for the NEG condition over the AFF one can be traced back to the pattern of fixations attested in the dyslexic group, which could be an effect of the small group size. In the condition with two potential targets, the target preference reached .64 in the AFF condition but only .48 in the NEG one. In the condition with three potential targets, despite the high base probability of target fixation (.75), in the NEG condition the target preference stopped at .63 against the .81 in the AFF baseline.

The presence of a significant *group* × *number of targets* interaction (β = - 0.06, t = - 2.75, p = .005) indicates that the target preference in the two groups of participants was differently affected by the number of potential targets displayed in the visual scene. To investigate the nature of this interaction, data were split according to *group*, and the effect of *number of targets* was investigated for these subsets. Results showed a significant effect of *number of targets* on target preference for both controls (x2 = 96.64, df = 2, p < .001) and dyslexics (x2 = 14.91, df = 2, p < .001). However, as can be observed in the two graphs in Figure 6.6, the increase in target fixations was more pronounced from one experimental condition to another for dyslexics than for controls (.36, .53, .75 for dyslexics in the conditions with one, two, and three potential targets; .44, .58, .70 for controls in the same conditions).

To conclude, these findings confirm the preliminary observations reported in the descriptive analyses on the target. First, we found an increased penalty in target identification in the NEG condition compared to the AFF baseline at the increase in the number of potential targets displayed in the visual scene. However, this effect seemed to be more pronounced between experimental conditions with two and three potential targets for dyslexics but not for controls. Second, no significant differences were reported between the performance of the two groups, suggesting that dyslexics and controls adopted similar processing strategies for the computation of both affirmative and negative sentences with no evidence of specific processing difficulties displayed by dyslexics.

Descriptive analysis on the mentioned argument

The previous analyses on the target revealed that both groups of participants displayed a greater processing penalty for negative sentences, compared to the affirmative baseline, as the number of potential targets increased. In addition, no significant group differences were attested, indicating that dyslexics and controls adopted the same processing strategies for the computation of both affirmative and negative sentences. Crucially, in the negative condition, an increase in the pictures of potential targets corresponds to a decrease in the pictures of the mentioned argument: while in the affirmative condition the pictures of the mentioned argument correspond in fact to the potential targets, in the negative condition they are the pictures to avoid, as they represent the negated situation. It seems, therefore, that both controls and dyslexics were faster in target identification in the NEG condition when more visual competitors (i.e., pictures of the mentioned argument) were displayed in the visual scene.

In this last analysis, we seek visual confirmation of whether the effects reported for the NEG condition are driven by participants exploiting the visual representation of the mentioned argument during the time-course of negative sentence comprehension. In order to do so, we briefly compare the looking pattern behaviour across experimental conditions including a different number of MA pictures for each group of participants. Given that, in the NEG condition, looks towards the mentioned argument denote a delay in target identification, we are mainly interested in the moment in which the eye gaze pattern in this condition deviates from that in the AFF one, as it indicates when negation starts to affect the time-course of sentence interpretation.

The graphs in Figure 6.7 show the proportion of looks to the mentioned argument (i.e., Aladdin closing the door in (6)) after the Disambiguation Point, computed in 50ms time-slots for controls (Fig. 6.7a-c) and dyslexics (Fig. 6.7d-f). From top to bottom, we have the conditions including one (a-d), two (b-e), and three (c-f) pictures of the mentioned argument. The affirmative condition (AFF) is plotted in blue: here, the picture of the mentioned argument represents the target of sentence (6). The negative condition (NEG) is plotted in red: here, the picture of the mentioned argument is the picture to avoid (i.e., the negated state of affairs). The horizontal axis shows the selected time period, and time point 0-ms corresponds to the DisP onset. The vertical line indicates the beginning of the broad time-window identified in the previous analyses as our major area of interest.

(6) Aladdin is/is not [DisP] closing the door

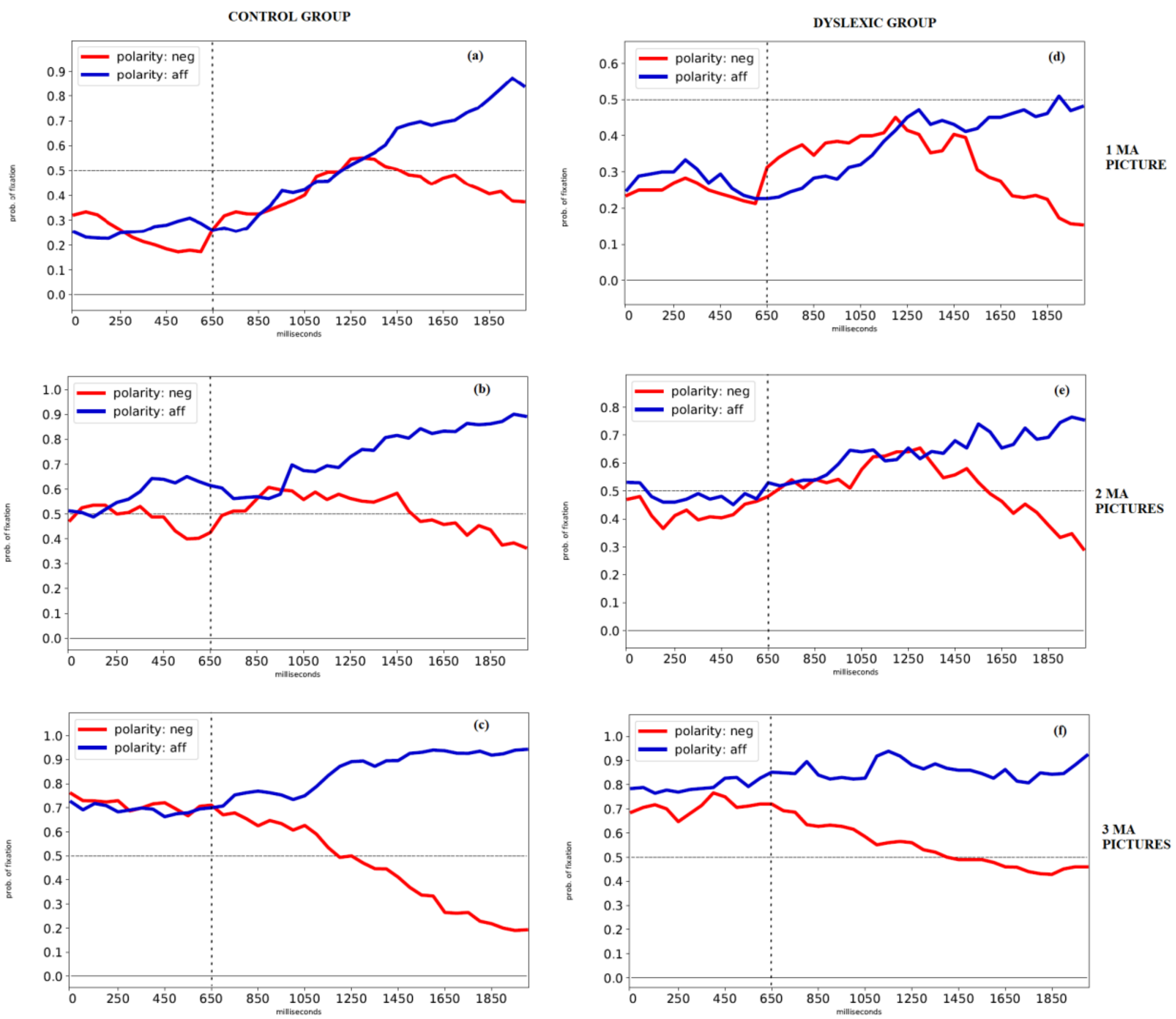

Figure 6.7. Proportion of looks to the mentioned argument (i.e., Aladdin closing the door in (6)) for controls (6.7a-c) and dyslexics (6.7d-f) including one (a-d), two (b-e), and three (c-f) pictures of the mentioned argument.

One mentioned argument. Graphs (6.7a) and (6.7d) depict the experimental condition including only one picture of the mentioned argument (MA): for the NEG condition, the visual scenario includes three potential targets. After the disambiguation offset, we see an initial pattern of MA fixations in both the AFF (blue line) and the NEG (red line) conditions in both graphs, indicating that both dyslexics and controls were looking at the picture of the mentioned argument at almost the same rate regardless of sentence polarity. In the control group (6.7a), the two lines depart in opposite directions about 700ms after the disambiguation offset (1350ms in the graph): at this point, participants started shifting their gaze towards the actual target of the negative sentence. In the dyslexic group (6.7d), this deviation occurred about 200ms later (1550ms in the graph). Overall, this pattern of fixations reveals that, despite the very high base probability of target fixations in this experimental condition (.75), when presented with negative sentences both groups of participants were looking at the picture of the mentioned argument (i.e., the visual competitor) for almost one second after the offset of the disambiguation.

Two mentioned arguments. Graph (6.7b) and (6.7e) show the experimental condition including two pictures of the mentioned argument: the visual scenario includes two potential targets for both AFF and NEG sentences. For controls (6.7b), we see that the eye gaze pattern in the NEG condition started to deviate from that in the AFF one at 400ms after the disambiguation offset (1050ms in the graph), and MA fixations decreased below chance level (.50) at about 1450ms in the graph. Only from this point onwards, controls started to look more steadily at the target picture than at the mentioned argument. For dyslexics, graph (6.7e) shows that the blue line (AFF) and the red line (NEG) overlap for about 600ms after the disambiguation offset, indicating that dyslexics were looking at the MA picture at almost the same rate in both the AFF and the NEG conditions. At 1350ms in the graph, MA fixations started to decrease in the NEG condition, as dyslexics' visual attention converged towards the actual target of the NEG sentence. All in all, both groups showed a similar pattern of MA fixations in the NEG condition with two pictures of the mentioned argument. Moreover, we can notice that participants were faster at shifting their gaze towards the actual target of the negative sentences compared to the condition with one MA picture.

Three mentioned arguments. Graph (6.7c) and (6.7f) depict the experimental condition including three pictures of the mentioned argument: for the NEG condition, the visual scenario includes only one target picture. A visual inspection of the two graphs reveals that the blue line (AFF) and the red line (NEG) do not overlap after the disambiguation offset in neither the control nor the dyslexic group. Despite the high base probability of MA fixations in this experimental condition (.75), both controls (6.7c) and dyslexics (6.7f) showed a rapid decrease of MA fixations in the NEG condition immediately after the disambiguation offset, indicating that they disambiguated the visual referent of the negative sentence very quickly. Altogether, a similar pattern of MA fixations in the NEG condition can be observed for both groups. In addition, compared to the NEG conditions with one and two pictures of the mentioned argument, participants were remarkably faster at identifying the target picture.

In conclusion, the comparison of participants' looking pattern behaviour across experimental conditions confirms a facilitating effect of the visual prominence of the mentioned argument on the interpretation process: in the NEG condition, both dyslexics and controls were faster at shifting their gaze towards the actual target of the negative sentence as the number of pictures of the mentioned argument (i.e., the visual competitor) increased. Furthermore, very similar patterns of fixations towards the mentioned argument were reported for the two groups in each experimental condition, providing further confirmation that negative sentences were processed in a similar way by controls and dyslexics.

6.3.3.2 Black and white geometric shapes

Descriptive analysis on the target

One potential target. The graphs in Figure 6.8 show the proportion of looks to the target after the Disambiguation Point (7), computed in 50ms time-slots, for controls (a) and dyslexics (b) in the experimental condition including one potential target. The affirmative condition (AFF) is plotted in blue, whereas the negative condition (NEG) is plotted in red. The horizontal axis shows the selected time period, and time point 0-ms corresponds to the DisP onset. Vertical lines are drawn accordingly to the time-window identified as our major area of interest (650ms-2150ms) and used in the statistical analysis below. In this condition, the base probability of target fixation is .25, as there is only one possible referent of the verbal description among the four pictures displayed in the visual scene.

(7) There is/is not [DisP] a pentagon

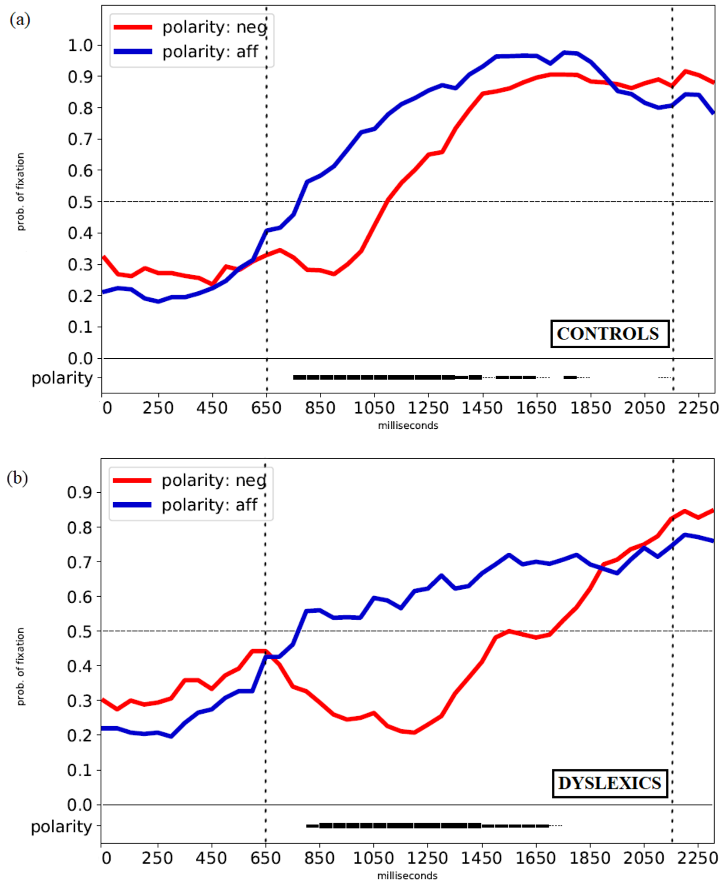

Figure 6.8. Proportion of looks to the target for AFF (blue) and NEG (red) sentences in the condition with one potential target for controls (a) and dyslexics (b). The black segments at the bottom display the significance of the main effect of polarity.

For the control group, the graph (6.8a) shows a rapid increase of target fixations immediately after the disambiguation offset with affirmative sentences. Instead, with negative sentences, target fixations arose above chance level (.25) only 300ms after the offset of the disambiguation (950ms in the graph). In addition, the absolute proportion of looks to the target is higher in the AFF condition than in the NEG one for almost the entire duration of our area of interest (650ms-2150ms), as indicated by the fact that the blue line (AFF) is above the red line (NEG) until 1950ms after the disambiguation onset. This difference in target preference between the AFF and the NEG condition results in a significant main effect of *polarity* between 750ms and 1450ms, between 1550ms and 1650ms, and in the 50ms time-slot between 1750ms and 1850ms (see Appendix C; Table 6.4). Taken together, these results reveal a difference between AFF and NEG conditions with respect to the exact moment in which the target is disambiguated, with controls being slower at identifying the target in the NEG condition than in the AFF one.

For dyslexics, a visual inspection of graph (6.8b) reveals an increase of fixations towards the target immediately after the offset of the disambiguation in the AFF condition. On the contrary, in the NEG condition, we can observe that target fixations did not arise above chance level (.25) until 600ms after the disambiguation offset (1250ms in the graph), when they started to rapidly increase. Moreover, the blue line (AFF) is above the red line (NEG) until 1950ms after the onset of the disambiguation, indicating that participants were looking more often at the target picture in the affirmative condition than in the negative one. This difference in target preference between the two conditions results in a significant main effect of *polarity* between 800ms and 1700ms (see Appendix C; Table 6.4). All in all, this pattern of fixations suggests that also dyslexics were slower in target identification when presented with negative sentences than with the corresponding affirmative ones.

Summarizing, these results point to a significant advantage in target identification for the AFF condition over the NEG one for both groups: in other words, participants were faster at identifying the target when presented with the affirmative sentence. If we compare the two graphs in Figure 6.8, we can observe that, in the NEG condition, dyslexics were looking at the competitor (i.e., the mentioned argument) longer and more steadily than controls before their attention converged towards the target picture, as suggested by the fact that target fixations for the dyslexic group did not rise above chance level until 600ms after the disambiguation offset. Furthermore, it seems that from a visual inspection of the graphs controls displayed higher target preference values in both the AFF and the NEG condition compared to dyslexics within our whole area of interest (650ms-2150ms). For instance, at 600ms after the disambiguation offset (1250ms in the graph), the target preference for the control groups is .70 in the NEG condition and .85 in the AFF one, whereas for the dyslexic group it amounts to .25 in the NEG condition and .60 in the AFF one, respectively. At the end of our area of interest, target preference is higher than .80 in both AFF and NEG condition for the control group, whereas it has reached .70 for the AFF condition and .80 for the NEG one in the dyslexic group. This difference in target preference values between the two groups points to an overall processing penalty for dyslexics in accomplishing the reference resolution task, which will be further investigated with a statistical analysis in the following section.

Two potential targets. The graphs in Figure 6.9 depict the proportion of looks to the target after the Disambiguation Point, computed in 50ms time-slots, for controls (a) and dyslexics (b) in the experimental condition including two potential targets. The affirmative condition (AFF) is plotted in blue, and the negative condition (NEG) is plotted in red. Vertical lines are drawn accordingly to the time-window identified as our major area of interest (650ms-2150ms). In this condition, the base probability of target fixation is .50, as there are two possible visual referents of the verbal description out of the four pictures displayed in the visual scene.

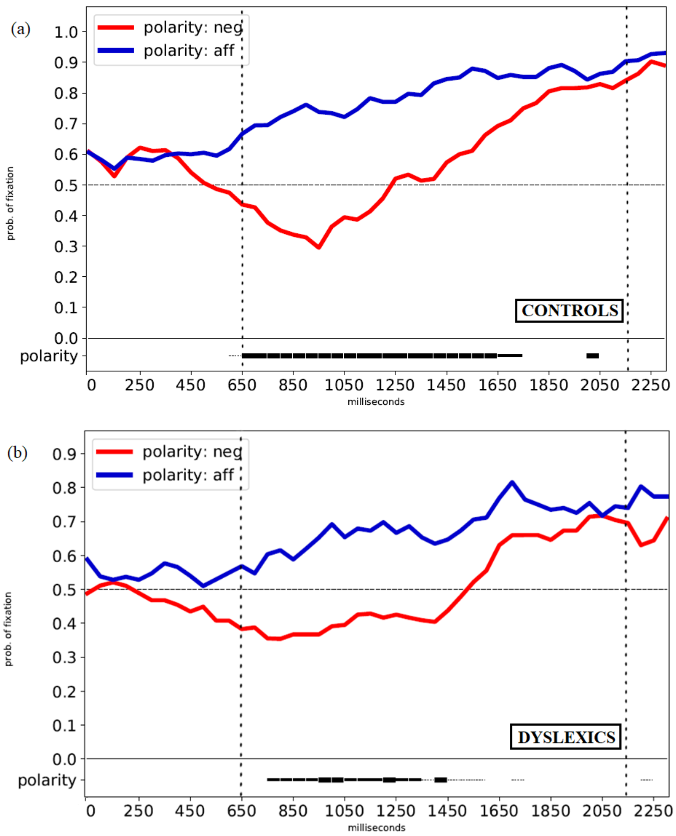

Figure 6.9. Proportion of looks to the target for AFF (blue) and NEG (red) sentences in the condition with two potential targets for controls (a) and dyslexics (b). The black segments at the bottom display the significance of the main effect of polarity.

For the control group, graph (6.9a) shows an opposite pattern of target fixations for the AFF and the NEG conditions at the disambiguation offset. In the AFF condition, there was an immediate increase of fixations towards the target, that reached .90 at the end of our area of interest (2150ms in the graph). Instead, in the NEG condition, we can see that target fixations suddenly decreased, with target preference dropping to .30 at 950ms after the onset of the disambiguation. Here, the fixations towards the target picture started to increase, exceeding chance level (.50) only 600ms after the offset of the disambiguation (at 1250ms in the graph) and reaching .80 at the end of our area of interest. Furthermore, the absolute proportion of looks to the target is always higher in the AFF condition than in the NEG one, as indicated by the fact that the blue line (AFF) is above the red line (NEG) for the entire broad time-window (650ms-2150ms). This difference in target preference between the two conditions is revealed significant between 650ms and 1750ms and in the 50ms time-slot between 2000ms and 2050ms (see Appendix C; Table 6.5). Overall, the different looking pattern behaviour between the two conditions suggests that participants were faster at disambiguating the target picture in the AFF condition than in the NEG one: in the latter, the initial decrease in target fixations below chance level indicates that participants, after the offset of the disambiguation, were looking more often at the competitor (i.e., the mentioned argument), and that the target picture was disambiguated about 600ms later than in the AFF baseline, when target fixations arose above chance level.

A similar pattern of fixations can be observed in graph (6.9b) for dyslexics. In the AFF condition, we notice that target fixations arose above chance level (.50) immediately after the disambiguation offset (650ms in the graph), indicating that the target has been rapidly disambiguated by dyslexics. Instead, in the NEG condition, the proportion of looks towards the target decreased below chance level after the offset of the disambiguation, with the participants' looks converging towards the target (> .50) only 900 later (at 1550ms in the graph). The difference between affirmative and negative sentences causes target preference in the AFF condition (blue line) to be above target preference in the NEG condition (red line) during our entire region of interest (650ms-2150ms). This results in a main effect of *polarity* between 50ms and 1450ms – almost significant between 1450ms and 1600ms, as well as in the 50ms time-slot between 1700ms and 1750ms, indicating a significant advantage in target identification for the AFF condition over the NEG one (see Appendix C; Table 6.5). All in all, this looking pattern behaviour suggests that similar to controls, dyslexics were slower in target identification in the NEG condition than in the AFF one, due to an initial greater uncertainty as to which picture (i.e., the target or the competitor) was the visual referent of the negative sentence.

To sum up, the results reveal a difference between AFF and NEG conditions with respect to target disambiguation: as in the experimental condition with one potential target, both groups of participants were slower at identifying the target when presented with negative sentences than with the corresponding affirmative ones. Significantly, this processing penalty displayed by the NEG condition in comparison to the AFF baseline seems to be due to an initial pattern of fixations towards the visual competitor (i.e., the mentioned argument) occurring immediately after the offset of the disambiguation in both groups. This aspect of the processing will be investigated in more detail with a descriptive analysis of the mentioned argument.

If we compare the two graphs in Figure 6.9, we can observe that, in the NEG condition, dyslexics were slower than controls at shifting their gaze towards the visual referent of verbal description, as revealed by the fact that target preference arose above chance level (.50) about 300ms later than in the control group. Nonetheless, when presented with negative sentences, controls seemed to look more steadily at the competitor (i.e., the mentioned argument) than dyslexics before target disambiguation, as indicated by lower target preference values in the first 300ms after the offset of the disambiguation. Furthermore, although similar patterns of fixations can be observed between the two groups, a visual inspection of the graphs suggests that controls displayed a more prominent increase of the target preference in both the AFF and the NEG conditions compared to dyslexics. Consider, for instance, the absolute proportion of looks to the target midway through our region of interest (i.e., 1400ms in the graph): in the control group, it amounts to .50 for the NEG condition and to .80 for the AFF one, whereas, in the dyslexic group, it amounts to .40 and .60, respectively. At the end of our area of interest (i.e., 2150ms in the graph), the target preference in the dyslexic group has reached .75 for the AFF condition and .70 for the NEG one, whereas, in the control group it is higher than .80 for both conditions. This difference, attested also in the experimental condition including one potential target, suggests a more general processing delay displayed by dyslexics in task execution, not limited to the computation of linguistic negation.

To conclude, the comparison between Figure 6.8 and Figure 6.9 shows that, within our region of interest (650ms-2150ms), the difference between AFF and NEG conditions in target preference is larger in the condition with two potential targets for the control group. Instead, this difference seems minimal, at least visually, for dyslexics. Possible group differences in target identification across conditions will be analysed in detail with the statistical analysis on the target.

Three potential targets. The graphs in Figure 6.10 depict the proportion of looks to the target after the Disambiguation Point, computed in 50ms time-slots, for controls (a) and dyslexics (b) in the experimental condition including three potential targets. The affirmative condition (AFF) is plotted in blue, and the negative condition (NEG) is plotted in red. Vertical lines are drawn accordingly to the time-window identified as our major area of interest (650ms-2150ms). In this condition, the base probability of target fixation is .75, as there are three possible visual referents of the verbal description out of the four pictures displayed in the visual scene.

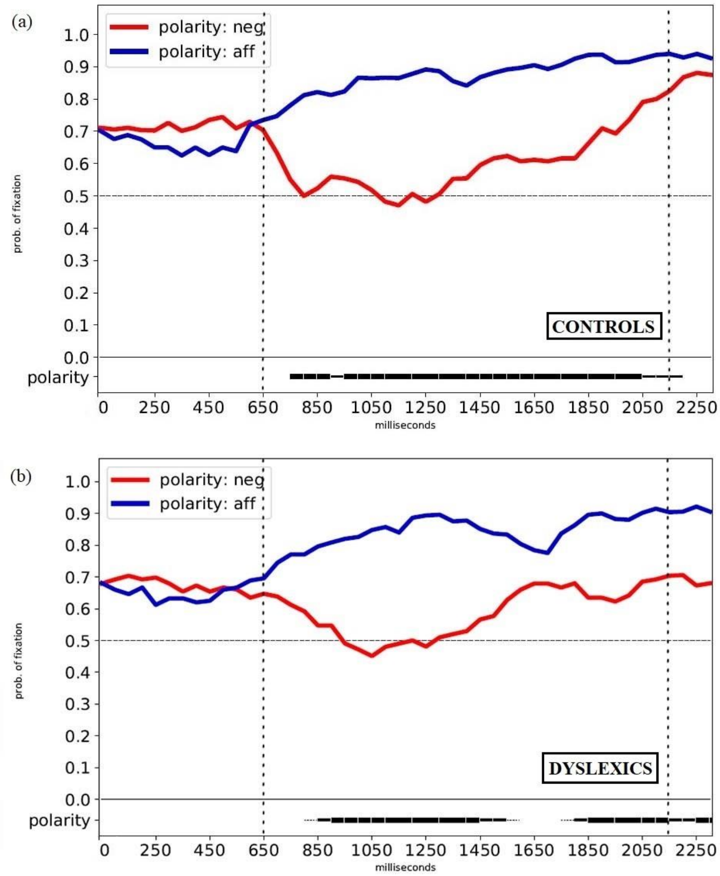

Figure 6.10. Proportion of looks to the target for AFF (blue) and NEG (red) sentences in the condition with three potential targets for controls (a) and dyslexics (b) The black segments at the bottom display the significance of the main effect of polarity.

A visual inspection of the two graphs in Figure 6.10 reveals a similar pattern of fixations in both the AFF and the NEG conditions between the two groups of participants. In the AFF condition, we can observe that the proportion of looks to the target immediately increases after the disambiguation offset for both controls (a) and dyslexics (b): at the end of our region of interest (at 2150ms in the graph), the target preference has reached .90 in both groups. Instead, we see a pronounced decrease of target fixations below chance level (.75), indicating that participants' visual attention converged towards the picture of the competitor (i.e., the mentioned argument): after the disambiguation offset, the target preference dropped for

600ms, reaching about .50 in both the control and the dyslexic group. Here, at 1250ms in the graph, participants' look towards the target started to increase. In the control group, the initial target preference value (.70) is reached 1300ms after the disambiguation offset (1950ms in the graph): at the end of our region of interest, the absolute proportion of looks to the target amounts to .80 in the NEG condition. In the dyslexic group, a target preference value similar to the initial one is reached one second after the offset of the disambiguation: however, unlike in the control group, we can see that the proportion of looks to the target does not depart from this value until the end of our broad time-window (2150ms in the graph).

In addition, we can observe that, in both groups, the blue line (AFF) is above the red line (NEG) for the entire region of interest (650ms-2150ms). The initial decrease of target fixations in the NEG condition results in a significant main effect of *polarity* in both groups, suggesting that the target was disambiguated faster in the AFF condition than in the NEG one (see Appendix C; Table 6.6). For the control group, the effect of *polarity* is revealed significant between 750ms and 2150ms; for dyslexics, between 850ms and 1550ms, and from 1850 onwards. This suggests that, even after target disambiguation, participants were looking at the target less steadily in the NEG condition than in the AFF baseline.

Taken together, these results reveal that the NEG condition displayed a significant delay in target identification compared to the AFF baseline in both groups. Crucially, in the experimental condition with three potential targets, the visual scene included, for the NEG condition, only one picture of the mentioned argument, corresponding to the negated situation. As discussed for cartoon characters (§6.3.3.1), the initial decrease in target preference reported for the NEG condition indicates that, despite the very high probability of target fixation (.75), participants were looking more often than in the AFF baseline at the picture of the mentioned argument after the disambiguation offset. This processing penalty will be further investigated with the descriptive analyses on the mentioned argument. In addition, if we observe the two graphs in Figure 6.10, we can notice similar pattern of fixations between the two groups in both the AFF and the NEG conditions, with similar target preference values in our area of interest (650ms-2150ms). This suggests no particular group differences during the time course of sentence interpretation in this experimental condition.

Finally, a visual comparison among Figure 6.8, Figure 6.9, and Figure 6.10 reveals that, in our area of interest (650ms-2150ms), the difference between AFF and NEG conditions in target preference remains constant across the experimental conditions including one (Figure 6.8b), two (Figure 6.9b), and three (Figure 6.10b) potential targets for dyslexics. Instead, for controls, we can observe that, at least visually, this difference is slightly larger in the condition with two potential targets (Figure 6.9a) compared to the condition with one potential target (6.8a), but not between the conditions with two (Figure 6.9a) and three (Figure 6.10a) potential targets. This suggests that controls were slower at identifying the target picture in the NEG condition compared to the AFF baseline as the number of potential targets increased from one to two. Instead, when presented with negative sentences, dyslexics' performance in target identification seems not to be affected by the number of potential targets displayed in the visual scene. This aspect of the processing will be further investigated with a statistical analysis in the following section.

Statistical analysis on the target

The previous analyses revealed an advantage in target identification for affirmative sentences over the negative ones for both groups of participants in all the three experimental conditions. For dyslexics, the processing penalty displayed by negation compared to the affirmative baseline remained constant regardless of the number of potential targets displayed in the visual scene. For controls, this difference in target preference was slightly more pronounced in the conditions with two and three potential targets than in the condition with only one target picture. In this section, we seek confirmation of whether target identification is significantly affected by sentence polarity, as well as by the interaction between sentence polarity and the number of potential targets. Moreover, we aim to assess possible statistically relevant differences between the two groups in target identification.

Figure 6.11 illustrates the target preference computed over the broad time-window of interest (650ms-2150ms) for all participants in the experimental conditions including one, two, and three potential targets. Figure 6.12 shows the target preference for each of the two groups: (a) for controls and (b) for dyslexics, respectively. The horizontal axis shows the three experimental conditions, and the vertical axis the absolute proportion of looks to the target(s). The means for each group are reported in the table below. The AFF condition is plotted in blue, and the NEG condition is plotted in red. In this analysis, the onset of the time-window was shifted 200ms after the relevant marker in the speech stream to account for saccade programming (Allopenna et al. 1998, Matin et al. 1993).

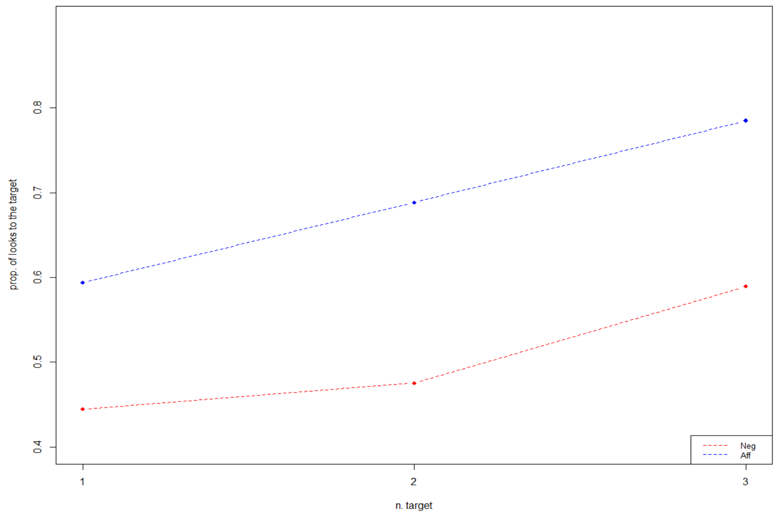

Figure 6.11. Overall proportion of looks to the target(s) in the broad time-window (650ms-2150ms) for in AFF (blue) and NEG (red) conditions including one, two, and three potential targets.

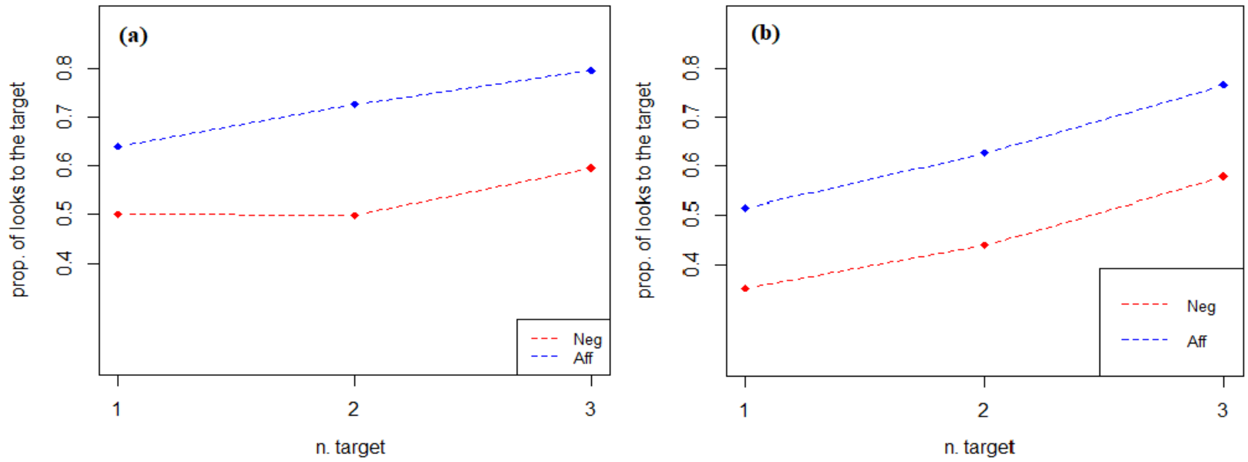

Figure 6.12. Proportion of looks to the target(s) in the broad time-window (650ms-2150ms) for the control (a) and the dyslexic (b) group in AFF (blue) and NEG (red) conditions including one, two, and three potential targets.

	Control Group		**Dyslexic Group**	
N. target	**AFF**	**NEG**	**AFF**	**NEG**
1	.64	.50	.51	.35
2	.72	.49	.62	.44
3	.79	.59	.76	.57

We calculated a linear-mixed effects regression model with *target preference* as dependent variable and *group* (controls vs. dyslexics), *number of targets* (1,2,3) and *polarity* (AFF vs. NEG) as independent variables using the packages lme4 and lmer Test in R (Bates et al. 2015, Kuznetsova et al. 2017). A logarithmic transformation has been applied to the target preference to make it suitable for statistical analysis (Jaeger 2008). Participants and items were added as crossed random effects (random intercepts). Random slopes for participants and items were included if this improved the fit of the model (as estimated by comparing the logLikelihoods of the models using the anova-function in R). Non-significant interactions were removed from the model.

Figure 6.11 shows an overall penalty in target identification in the NEG conditions in comparison to the AFF ones. This resulted in a significant main effect of *polarity* (β = - 0.18, t = -10.15, $p < .001$), revealing that both controls and dyslexics were remarkably slower in target identification when presented with negative sentences. The analysis yielded a main effect of *group* (β = -0.08, t = 3.16, $p = .004$), revealing that dyslexics were significantly slower in target identification than controls (.54 vs .63). If we observe the two graphs in Figure 6.12, we can see, in fact, lower target preference values for dyslexics compared to controls in all the experimental conditions. The absence of a *polarity* × *group* interaction indicates that the two groups were similarly affected by sentence polarity: as can be seen in Figure 6.12, the difference in target preference values between AFF and NEG conditions was similar for controls (AFF .72 vs NEG .53) and dyslexics (AFF .63 vs NEG .45).

The model also revealed a significant main effect of *number of targets* (β = 0.08, t = 8.03, $p < .001$), indicating that, as can be observed in Figure 6.11, participants were looking more often at the target when more target pictures were displayed in the visual scenario. However, it is worth noting that the reported effect can be the consequence of a different base probability of target fixation across the experimental conditions with one, two, and three potential targets (.25, .50, .75, respectively). The lack of a *polarity* × *number of targets* interaction indicates that the penalty in target identification carried by negative sentences compared to the affirmative baseline was constant throughout experimental conditions. This holds for both dyslexics and controls, without distinctions between groups, as demonstrated by the lack of a three-way interaction with *group*. This can be easily observed in the graphs in Figure 6.12, where, for both groups, the difference in target preference values between AFF (blue) and NEG (red) sentences is the very similar across conditions including a different number of target pictures.

To conclude, these findings confirm the preliminary observations reported in the previous descriptive analyses on the target. First, participants (both dyslexics and controls) were always slower in target identification when presented with negative sentences than with the corresponding affirmative ones. Second, this processing penalty displayed by negation was constant across experimental conditions including a different number of potential targets. Finally, it seems that dyslexics and controls resorted to the same processing strategies for the computation of both affirmative and negative sentences: however, the former were found to be overall slower than the latter in target identification. This points to a more generalized difficulty in the accomplishment of the reference resolution task, which cannot be ascribed to the computation of linguistic negation.

Descriptive analysis on the mentioned argument

The statistical analysis on the target showed that: i) both groups of participants were significantly slower at identifying the target when presented with negative sentences than with the corresponding affirmative ones; ii) the processing penalty conveyed by negation was constant across experimental conditions; iii) in both the AFF and the NEG conditions, dyslexics displayed lower target preference values than controls. Significantly, the descriptive analysis on the target suggested that the processing penalty displayed by the NEG condition in comparison with the AFF baseline could be traced back to an initial pattern of fixations towards the visual competitor (i.e., the mentioned argument) occurring immediately after the offset of the disambiguation. In addition, the visual inspection of the graphs indicated that dyslexics were looking at the picture of the mentioned argument longer and more steadily than controls before their attention converged towards the target picture.

In this analysis, we aim to assess whether the effects reported for the NEG conditions are indeed driven by patterns of fixations towards the picture(s) of the mentioned argument. In order to do so, we examine participants' looking behaviour across conditions including one, two, and three pictures of the mentioned argument, by focusing in particular on the moment in which the eye gaze pattern in the NEG condition deviates from that in the AFF one – as it corresponds to when negation is integrated into sentence meaning.

The graphs in Figure 6.13 depict the proportion of looks to the mentioned argument (i.e., the pentagon in (8)) after the Disambiguation Point, computed in 50ms time-slots, for controls (6.13a-c) and dyslexics (6.13d-f). From top to bottom, we have the conditions including one (a-d), two (b-e), and three (c-f) pictures of the mentioned argument. The affirmative condition (AFF) is plotted in blue: here, the picture of the mentioned argument represents the target of sentence (8). The negative condition (NEG) is plotted in red: here, the picture of the mentioned argument is the picture to avoid (i.e., the negated state of affairs). The horizontal axis shows the selected time period, and time point 0-ms corresponds to the DisP onset. The vertical line indicates the beginning of the broad time-window identified in the previous analyses as our major area of interest.

(8) There is/is not [DisP] a pentagon

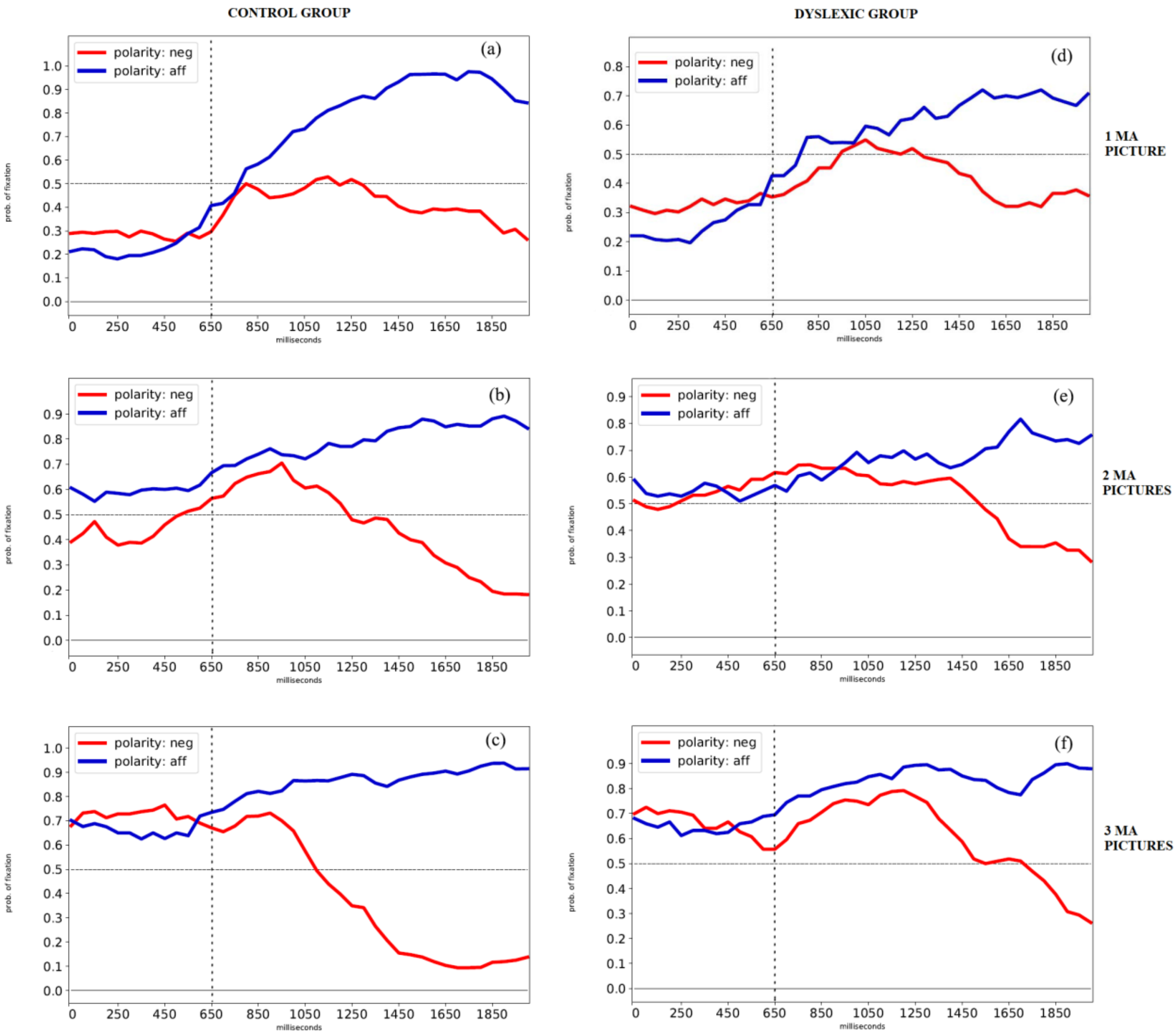

Figure 6.13. Proportion of looks to the mentioned argument (i.e., the pentagon in (8)) for controls (6.13a-c) and dyslexics (6.13d-f) including one (a-d), two (b-e), and three (c-f) pictures of the mentioned argument.

One mentioned argument. Graphs (6.13a) and (6.13d) show the experimental condition including one picture of the mentioned argument. The base probability of MA fixation is .25, as there is only one picture of the MA out of the four pictures displayed in the screen: for the NEG condition, the visual scenario includes three potential targets. After the disambiguation offset, both graphs show an initial overlap between the blue line (AFF) and the red line (NEG), suggesting that participants were looking at the picture of the mentioned argument in both the AFF and the NEG conditions. For controls (6.13a), we can see that the red line departs from the blue line about 250ms after the disambiguation offset, indicating that participants were shifting their gaze towards the actual target of the negative sentence. Instead, for dyslexics (6.13d), we can notice that the two lines depart in different directions about 400ms after the offset of the disambiguation. All in all, the visual comparison of the two groups reveals that, despite the very high base probability of target fixation in the NEG condition (.75), both groups were initially looking at the picture of the mentioned argument: moreover, dyslexics took longer than controls in shifting their gaze towards the actual target picture of the NEG sentence.

Two mentioned arguments. Graphs (6.13b) and (6.13e) depict the experimental condition including two pictures of the mentioned argument. The base probability of MA fixation is .50, as there are two pictures of the MA out of the four pictures displayed in the screen: for both the AFF and NEG condition, the visual scenario includes two potential targets. For controls, graph (6.13b) shows an increase of MA fixations for about 300ms after the offset of the disambiguation regardless of sentence polarity. Here, at 900ms in the graph, MA fixations started to rapidly decrease in the NEG condition, indicating target disambiguation. Instead, graph (6.13e) reveals that dyslexics were looking at the picture of the mentioned argument at almost the same rate in both the AFF and the NEG conditions for about 800ms after the disambiguation offset before their attention converged towards the visual referent of the negative sentence. Altogether, the visual inspection of the two graphs confirms an initial pattern of fixations towards the picture of the mentioned argument in the NEG condition for both groups of participants: as in the previous experimental condition, dyslexics took longer than controls in shifting their gaze towards the actual target of the negative sentence. Nonetheless, if we compare the looking pattern behaviour within each group, we can see that participants took approximately the same time to disambiguate the target in the NEG conditions with one and two MA pictures.

Three mentioned arguments. Graph (6.13c) and (6.13f) show the experimental condition including three pictures of the mentioned argument. Here, the chance level of MA fixation is .75, as there are three pictures of the MA out of the four pictures displayed in the screen: for the NEG condition, the visual scene includes only one target picture. For controls, graph (6.13c) reveals a similar pattern of fixations towards the mentioned argument in both the AFF and the NEG condition for about 300ms after the disambiguation offset. Then, there was a sudden decrease of MA fixations in the NEG one, indicating that controls were shifting their gaze towards the visual referent of the negative sentence. Conversely, graph (6.13f) shows that dyslexics' visual attention converged towards the MA pictures for about 600ms after the offset of the disambiguation, regardless of sentence polarity. Only at this point, MA fixations in the NEG condition decreased, indicating that the target picture has been disambiguated. Overall, these results reveal that, although both groups displayed an initial pattern of MA fixations in the NEG condition, controls were remarkably faster than dyslexics in disambiguating the actual target of the negative sentence. Furthermore, both dyslexics and controls took as long as in the other experimental conditions to look at the target of the negative sentence.

To conclude, our results confirm that the processing penalty displayed by NEG condition compared to the AFF baseline is due to an initial pattern of fixations towards the mentioned argument (i.e., the negated situation) for both groups of participants. In addition, the visual prominence of the mentioned argument did not have a facilitating effect on the processing of negative sentences, as revealed by the fact that, within each group, participants disambiguated the target picture at almost the same rate across experimental conditions including a different number of MA pictures. Finally, although the two groups displayed a very similar strategy for the processing of negative sentences, longer pattern of MA fixations were reported for dyslexics, providing further confirmation of an overall delay in target identification compared to controls.[109]

6.3.3.3 Coloured geometric shapes

Descriptive analysis on the target

One potential target. The graphs in Figure 6.14 depict the proportion of looks to the target after the Disambiguation Point (9), computed in 50ms time-slots, for controls (a) and dyslexics (b) in the experimental conditions including one potential target. The affirmative condition (AFF) is plotted in blue, and the negative condition (NEG) is plotted in red. The horizontal axis shows the selected time period, and time point 0-ms corresponds to DisP onset. Vertical lines are drawn accordingly to the time-window identified as our major area of interest (650ms-2150ms) and used in the statistical analysis below. In this condition, the base probability of target fixation is .25, as there is only one possible referent of the verbal description among the four pictures displayed in the visual scene.

(9) The triangle is/is not [DisP] green…

[109] The reader must bear in mind that the main focus of the present analysis was investigating possible patterns of fixations towards the picture of the mentioned argument occurring when participants were presented with negative sentences. The previous analysis on the target has revealed that the delay in target identification displayed by dyslexics was not limited to the computation of negative sentences, but it was rather evidence of more general difficulty in the reference resolution task, regardless of sentence polarity.

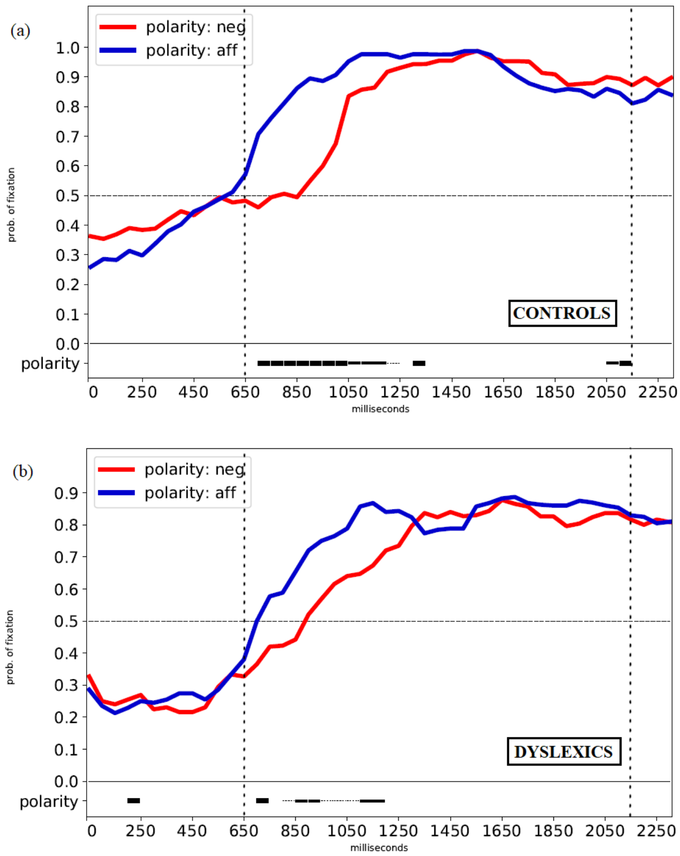

Figure 6.14. Proportion of looks to the target for AFF (blue) and NEG (red) sentences in the condition with one potential target for controls (a) and dyslexics (b). The black segments at the bottom display the significance of the main effect of *polarity*.

For the control group, the graph (6.14a) shows a rapid increase of target fixations immediately after the disambiguation offset for both affirmative and negative sentences. However, a closer visual inspection reveals that the target preference started to arise above chance level (.25) already during the unfolding of the critical word. At the onset of our major area of interest (650ms in the graph), the target preference has reached .50 for both the AFF and the NEG conditions, suggesting that participants disambiguated the target picture very quickly regardless of sentence polarity (< 650ms). Nonetheless, the absolute proportion of looks to the target is higher in the AFF condition (blue line) than in the NEG one (red line) for 600ms from the offset of the disambiguation. This difference in target preference between the two conditions results in a significant effect of *polarity* between 700ms and 1200ms, and in the 50ms time-slot between 1300ms and 1350ms, suggesting that controls were faster in target identification when presented with affirmative sentences than with the corresponding negative ones (see Appendix C; Table 6.7). In addition, we can observe that, from 1250ms in the graph onwards, the two lines almost overlap, indicating that participants are fixating the target picture at almost the same rate in both conditions, with target preference reaching a ceiling value (>

.90). Two time-slots are revealed significant between 2050ms and 2150ms, although this is not of great interest given that at the end of our broad time-window (2150ms in the graph) target preference is higher than .80 for both conditions. Taken together, these results indicate that, although the target has been disambiguated very quickly in both AFF and NEG conditions, controls were slower at identifying the target when presented with negative sentences.

A similar looking pattern behaviour can be observed in the dyslexic group, with graph (6.14b) showing a rapid increase of target fixations above chance level (.25) after the disambiguation offset in both the AFF and the NEG conditions. Like in the control group, this suggests that dyslexics shifted their visual attention towards the target picture very quickly regardless of the polarity of the sentence. However, we can see that the blue line (AFF) is above the red line (NEG) from the onset of our region of interest (650ms) until 1250ms from the disambiguation onset: this indicates that, for about 600ms from the disambiguation offset, dyslexics were looking more often at the target picture in the affirmative condition than in the negative one. This different looking pattern behaviour between the two conditions results in a significant main effect of *polarity* in the 50ms time-slot between 700ms and 750ms, between 850ms and 950ms, and between 1100ms and 1200ms – nearly significant between 950ms and 110ms and in the 50ms time-slot between 800ms and 850ms (see Appendix C; Table 6.7). From 1250ms onwards, the two lines overlap and target preference is stable at .80, revealing that dyslexics were steadily looking at the same picture (i.e., the target) in both the AFF and the NEG condition.

To sum up, the results point to an advantage in target identification for the AFF condition over the NEG one for both groups: although participants' visual attention converged towards the target very quickly in both conditions, participants were faster at fixating the target picture when presented with the affirmative sentence. In addition, similar patterns of fixations can be observed between the two groups, but a visual comparison of the graphs reveals a more prominent increase of target fixations in the control group (6.14a) than in the dyslexic one (6.14b) with both affirmative and negative sentences. For instance, at the offset of the disambiguation (650ms in the graph), target preference has already reached .50 for the control group in both conditions, whereas it amounts to .35 for the dyslexic group. At 500ms after the disambiguation offset (1150ms in the graph), the absolute proportion of looks to the target has reached .90 in the AFF condition and .80 in the NEG one for controls, whereas for dyslexics it amounts to .80 and .70, respectively.

This difference in target preference suggests that dyslexics were overall slower than controls in the execution of the reference resolution task, and this delay seems not directly related to the presence of linguistic negation. This aspect of the processing and possible group differences will be investigated in detail in the statistical analysis on the target.

Two potential targets. The graphs in Figure 6.15 depict the proportion of looks to the target after the Disambiguation Point, computed in 50ms time-slots, for controls (a) and dyslexics (b) in the conditions including two potential targets. The affirmative condition (AFF) is plotted in blue, and the negative condition (NEG) is plotted in red. In this experimental condition, the base probability of the target fixation is .50, as there are two possible visual referents of the verbal description out of the four pictures displayed in the visual scene.

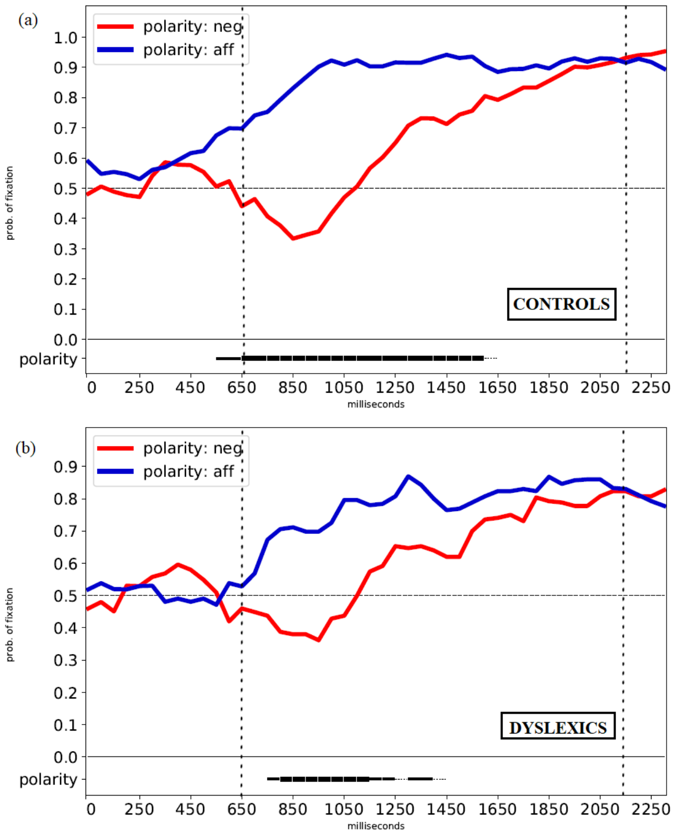

Figure 6.15. Proportion of looks to the target for AFF (blue) and NEG (red) sentences in the condition with two potential targets for controls (a) and dyslexics (b). The black segments at the bottom display the significance of the main effect of *polarity*.

For the control group, graph (6.15a) shows a rapid increase of target fixations in the AFF condition, with target preference reaching .90 within 250ms after the disambiguation offset. This clearly indicates that, when presented with affirmative sentences, controls were very quick in identifying the visual referent of the verbal description. Instead, the opposite pattern can be observed in the NEG condition, where the absolute proportion of looks towards the target suddenly decreased below chance level (.50) for about 200ms after the offset of the disambiguation, reaching .35 at 850ms in the graph. Here, the fixations towards the target started to increase, and arose above chance level 400ms after the disambiguation offset (1050ms in the graph). At the end of our region of interest (2150ms in the graph), target preference has reached .90 in both the AFF and the NEG condition. The different looking pattern behaviour between the two conditions causes target preference in the AFF condition (red line) to be above that in the NEG condition (red line) during our entire area of interest (650ms-2150ms). The decrease in target fixations in the NEG condition results in a significant main effect of *polarity* throughout 650ms and 1600ms – quasi-significant in the next 50ms time-slot (see Appendix C; Table 6.8).

All in all, these results indicate that controls were slower in target identification when presented with negative sentences than with the corresponding affirmative ones. Interestingly, the different looking pattern behaviour attested between the two conditions can be already noticed during the unfolding of the critical word (> 650ms). From a visual inspection of the graph we can see, in fact, that the two lines depart in opposite directions at about 350ms from the onset of the disambiguation, resulting in a main effect of polarity between 550ms and 650ms. This suggests that the linguistic input was processed fast, affecting participants' looking pattern behaviour very early during the unfolding of the linguistic input.

Graph (6.15b) shows a similar pattern of fixations for the dyslexic group. In the AFF condition, we can see an increase of looks towards the target, which arose above chance level (.50) immediately after the disambiguation offset. Conversely, in the NEG condition, target fixations decreased below chance level for about 300ms after the disambiguation offset, reaching .35 at 950ms in the graph. Then, target preference started to increase, with participants' looks converging towards the target (> .50) from 1100ms onwards. At the end of our region of interest (at 2150ms in the graph), target preference has reached .80 in both AFF and NEG conditions. Like in the control group, the absolute proportion of looks to the target is always higher in the AFF condition than in the NEG one, as indicated by the fact that the blue line (AFF) is above the red line (NEG) for the entire broad time-window (650ms-2150ms), suggesting that dyslexics were faster in target identification when presented with affirmative sentences than with the corresponding negative ones. This difference in target preference values between the two conditions is revealed significant between 750ms and 1250ms, and between 1300ms and 1400ms – nearly significant in the 50ms time-slots 1250ms-1300ms and 1400ms-1450ms, respectively (see Appendix C; Table 6.8).

All in all, these results indicate that both groups of participants were slower at identifying the visual referent of the verbal description in the NEG condition than in the AFF baseline. Crucially, this processing penalty displayed by negation can be traced back to an initial pattern of fixations towards the visual competitor (i.e., the mentioned argument) reported for both groups immediately after the disambiguation offset, as indicated by target preference values initially decreasing below chance level. If we compare the two graphs in Figure 6.15, it seems that controls (a) displayed a more prominent increase of target fixations in the AFF condition compared to dyslexics (b). At the offset of the disambiguation, the absolute proportion of looks to the target amounts to .70 for controls and to .55 for dyslexics: after 250ms, it is .90 for the former and .70 for the latter. This difference in target preference values suggests that, in the AFF condition, dyslexics were looking at the target picture less steadily than controls, even after target disambiguation. Instead, we can observe similar target preference values between the two groups in the NEG condition, suggesting that negative sentences were similarly processed by controls and dyslexics.

To conclude, the comparison between Figure 6.14 and Figure 6.15 shows that, in our area of interest (650ms-2150ms), the difference between AFF and NEG conditions in the target preference is remarkably larger in the condition with two potential targets for both groups. This suggests that, despite the higher base probability of target fixation in this experimental condition, both controls and dyslexics displayed a greater processing penalty in target identification in the NEG condition compared to the AFF baseline.

Three potential targets. The graphs in Figure 6.16 depict the proportion of looks to the target after the Disambiguation Point, computed in 50ms time-slots, for controls (a) and dyslexics (b) in the conditions including three potential targets. The affirmative condition (AFF) is plotted in blue, and the negative condition (NEG) is plotted in red. In this experimental condition, the base probability of target fixation is .75, as there are three possible visual referents of the verbal description out of the four pictures displayed in the visual scene.

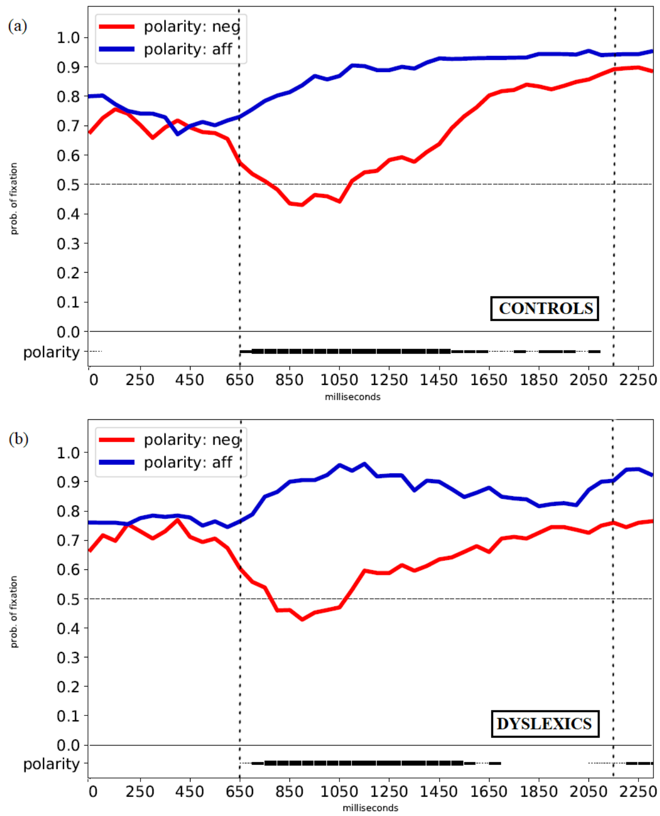

Figure 6.16. Proportion of looks to the target for AFF (blue) and NEG (red) sentences in the condition with three potential targets for controls (a) and dyslexics (b). The black segments at the bottom display the significance of the main effect of *polarity*.

If we compare the graphs in Figure 6.16, we can observe a very similar pattern of fixations in both the AFF and the NEG condition between the two groups. In the AFF condition, participants' looks towards the target rapidly increased after the offset of the disambiguation for both controls (a) and dyslexics (b): from 400ms after the disambiguation offset onwards, target preference is higher than .80 in both groups, indicating that the target picture has been disambiguated very quickly. Conversely, we can see that target fixations rapidly decreased below chance level (.75) in the NEG condition, suggesting that participants were looking more often at the picture of the competitor (i.e., the mentioned argument). After the disambiguation offset, target preference dropped for about 200ms, reaching .45 in both groups. Here, at 850ms, in the graph, participants' looks towards the target started to increase: in the control group, target fixations arose above chance level (.75) one second after the offset of the disambiguation (1650ms in the graph), whereas in the dyslexic group this target preference value is exceeded 200ms later, at 1850ms in the graph. This suggests that, in the NEG condition, dyslexics were looking at the target less steadily than controls even after target disambiguation (i.e., after the increase in target fixations). At the end of our region of interest (2150ms) target preference has reached, in the NEG condition, .85 for controls and .75 for dyslexics.

Furthermore, we notice that the blue line (AFF) is above the red line (NEG) for the entire broad time-window (650ms-2150ms). The different looking pattern behaviour between the AFF and the NEG conditions results in a significant effect of *polarity* in both groups, suggesting that participants were slower in target identification when presented with negative sentences than with the corresponding affirmative ones (see Appendix C; Table 6.9). For controls, the effect of *polarity* is revealed significant between 650ms and 1650ms, between 1850ms and 2000ms, and in two 50ms time-slots, 1750ms-1800ms and 2050ms-2100ms, respectively – quasi-significant between 1650ms and 1800ms, and between 2000ms and 2050ms. For dyslexics, between 700ms and 1650ms – nearly significant between 600ms and 650ms, and between 2050ms and 2150ms.

Taken together, these findings suggest that the NEG condition displayed a significant delay in target identification compared to the AFF baseline in both groups of participants. As discussed for the other item types (§6.3.3.1 for cartoon characters and §6.3.3.2 for black and white geometric shapes), this processing penalty in the NEG condition seems attributable to the fact that, despite the very high probability of target fixation in this experimental condition (.75), after the offset of the disambiguation participants were looking more often than in the AFF baseline at the fourth picture displayed in the visual scene, that is, the picture of the mentioned argument. This aspect of the processing will be explored more in detail with the descriptive analyses on the mentioned argument. Moreover, the comparison between the two graphs in Figure 6.16 reveals a similar pattern of fixations between the two groups in both the AFF and the NEG conditions, with similar target preference values in our area of interest (650ms-2150ms). This suggests that both AFF and NEG sentences were processed in a similar way by the two groups.

Finally, if we compare Figure 6.15 and Figure 6.16, we can observe that the difference between AFF and NEG conditions in target preference is larger in the condition with three potential targets, but, crucially, only for dyslexics. Instead, this difference seems minimal, at least visually, for controls. Overall, this suggests that, when presented with negative sentences, dyslexics were remarkably slower in target identification when more potential targets were displayed in the visual scene, compared to the affirmative baseline. Instead, this effect is smaller for controls between the conditions with two and three potential targets. This aspect of the processing and possible group differences will be further investigated with a statistical analysis in the following section.

Statistical analysis on the target

The previous analyses suggest that participants (both controls and dyslexics) were slower in target identification in all the three NEG conditions compared to the corresponding affirmative ones. In addition, the processing penalty displayed by NEG was greater at the increase in the number of potential targets displayed in the visual scene. Remarkably, this effect seemed to be more pronounced for dyslexics. For the control group, this penalty appeared stable between the NEG conditions with two and three target pictures. In this section, we will further investigate how sentence polarity and its interaction with the number of target pictures might affect the process of target identification. Moreover, we aim to assess possible relevant differences between the performance of the two groups in target identification.

Figure 6.17 illustrates the target preference computed over the broad time-window of interest (650ms-2150ms) for all participants in the experimental conditions including one, two, and three potential targets. Figure 6.18 shows the target preference for each of the two groups: (a) for controls and (b) for dyslexics, respectively. The horizontal axis shows the three experimental conditions, and the vertical axis the absolute proportion of looks to the target(s). The means for each group are reported in the table below the graphs. The AFF condition is plotted in blue, and the NEG condition is plotted in red. In this analysis, the onset of the time-window was shifted 200ms after the relevant marker in the speech stream for the time it would take to program a saccadic eye movement (Allopenna et al. 1998, Matin et al. 1993).

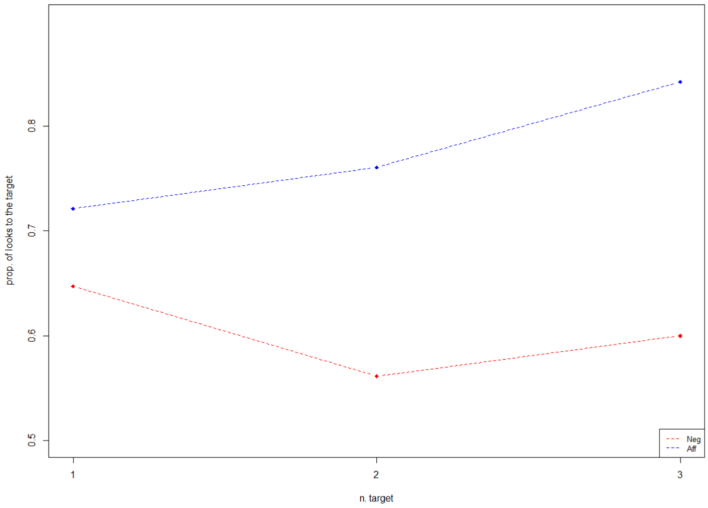

Figure 6.17. Overall proportion of looks to the target(s) in the broad time-window (650ms-2150ms) for in AFF (blue) and NEG (red) conditions including one, two, and three potential targets.

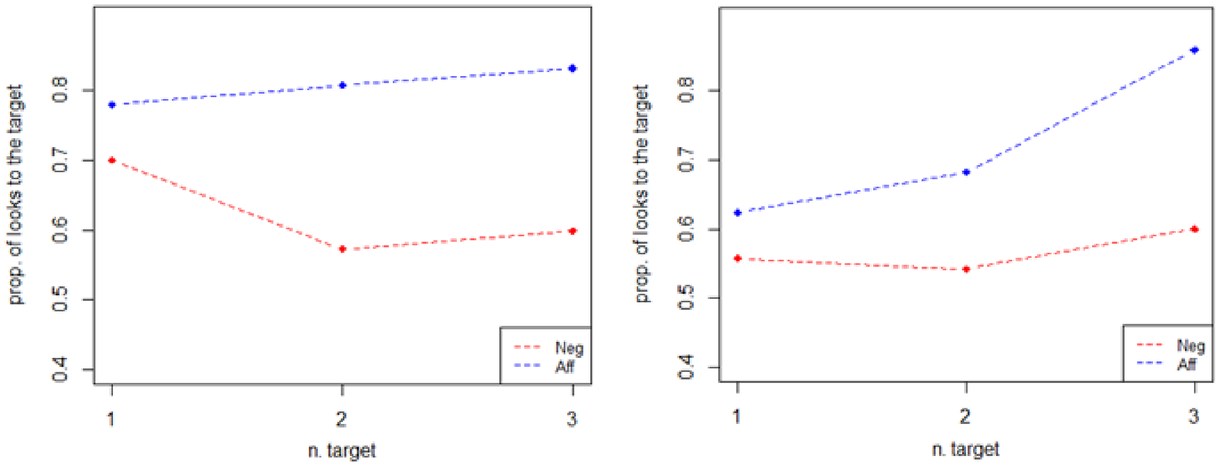

Figure 6.18. Proportion of looks to the target(s) in the broad time-window (650ms-2150ms) for the control (a) and the dyslexic (b) group in AFF (blue) and NEG (red) conditions including one, two, and three potential targets.

	Control Group		**Dyslexic Group**	
N. target	**AFF**	**NEG**	**AFF**	**NEG**
1	.78	.70	.62	.56
2	.81	.58	.68	.54
3	.83	.60	.86	.60

We calculated a linear-mixed effects regression model with *target preference* as dependent variable and *group* (controls vs. dyslexics), *number of targets* (1,2,3) and *polarity* (AFF vs. NEG) as independent variables using the packages lme4 and lmer Test in R (Bates et al. 2015, Kuznetsova et al. 2017). A logarithmic transformation has been applied to the target preference to make it suitable for statistical analysis (Jaeger 2008). Participants and items were added as crossed random effects (random intercepts). Random slopes for participants and items were included if this improved the fit of the model (as estimated by comparing the logLikelihoods of the models using the anova-function in R). Non-significant interactions were removed from the model.

Figure 6.17 shows a systematic penalty in target identification in the NEG condition compared to the AFF baseline. This resulted in a significant main effect of *polarity* ($ß$ = -0.17, t = -9.97, p < 0.001) confirming that participants were looking significantly more often at the target picture when presented with affirmative sentences than with the corresponding negative ones.

The model also revealed a main effect of *group* (β = 0.07, t = 2.14, p = .043), indicating that dyslexics were significantly slower than controls in target identification. In the two graphs in Figure 6.18, we can observe that dyslexics display lower target preference values than controls in most of the experimental conditions. In particular, this holds for AFF conditions with one and two potential targets, and for the NEG condition with only one potential target. The absence of a *polarity × group effect* reveals that controls (AFF .80 vs. NEG .62) and dyslexics (AFF .72 vs. NEG .56) had similar target preference values in AFF and NEG conditions. All in all, this suggests that dyslexics experienced a general difficulty in the reference resolution task, independent of polarity.

Moreover, a significant main effect of *number of targets* was reported (*ß* = 0.15, t = 2.87, $p < 0.001$), indicating that participants were looking more often at the target picture as the number of target pictures displayed in the visual scenario increased. However, as already pointed out in the statistical analyses with other item types, this effect might be related to the different base probability of target fixations across experimental conditions. The presence of a significant *group × number of targets* interaction (β = - 0.08, t = - 2.63, p = .015) indicates that the target preference in the two groups of participants was differently affected by the number of potential targets displayed in the visual scene. To investigate the nature of this interaction, data were split according to *group*, and the effect of *number of targets* was investigated for these subsets. For the controls, results showed that there was no significant effect of *number of targets* on target preference (x2 = 3.28, df = 2, p = .194), as revealed by similar values across experimental conditions: .74, .70, and .76 in the conditions with one, two, and three potential targets, respectively. Instead, for the dyslexics, results showed that they were looking significantly more often at the target as the number of potential target increased (x2 = 14.91, df = 2, $p < .001$): .59, .61, and .73 in the conditions with one, two, and three potential targets, respectively.

The analysis yielded a *polarity × number of targets* interaction (β = - 0.08, t = - 4.01, $p < .001$), revealing that the difference in target preference between the NEG condition and the corresponding AFF baseline becomes significantly more prominent at the increase in the number of potential targets displayed in the visual scene. To appreciate this result more in detail, we analysed the polarity by number of targets effect for the two groups of participants. Results showed the presence of a *polarity × number of targets* interaction for both the control (x2 = 12.26, df = 2, p = .002) and the dyslexic (x2 = 6.72, df = 2, p = .034) groups, confirming that, at the increase in the number of potential targets, both dyslexics and controls were looking at the target picture significantly less often when presented with negative sentences than with the corresponding affirmative ones. However, as can be observed in the two graphs in Figure 6.18, this effect was smaller for controls, as the penalty conveyed by negation is similar between the conditions with two (AFF .81 vs NEG .58) and three (AFF .83 vs NEG .60) potential targets.

To conclude, these findings confirm what observed in the preliminary descriptive analyses on the target regarding important aspects of sentence processing. First, participants (both controls and dyslexics) were faster in target identification when presented with affirmative sentences than with the corresponding negative ones. Second, the processing penalty displayed by negative sentences compared to the affirmative baseline increased when more target pictures were displayed in the visual scenario. Significantly, dyslexics were overall slower than controls in target identification. As discussed in the statistical analysis on the target for black and white geometric shapes, this suggests a more general impairment in the processing of both affirmative and negative sentences.

Descriptive analysis on the mentioned argument

The previous analyses on the target revealed that both groups of participants displayed a significant processing penalty in target identification when presented with negative sentences than with the corresponding affirmative ones. Crucially, this penalty carried by the NEG condition worsened at the increase of the number of target pictures displayed in the visual scene. Note that the ratio between the number of potential targets and the number of pictures of the mentioned argument is directly proportional in the affirmative condition, but inversely proportional in the negative one. As discussed for cartoon characters (§6.3.3.1), in the negative condition, participants were faster in target identification when more pictures of the mentioned argument (i.e., competitors) were present in the visual scene.

The aim of this exploratory analysis is to assess whether such an effect is attributable to possible patterns of fixations towards the picture(s) of the mentioned argument, as suggested by the descriptive analysis on the target. As for the other item types, we explore participants' looking pattern behaviour across experimental conditions including a different number of pictures of the mentioned argument, by paying particular attention to the moment in which the eye gaze pattern in the NEG condition deviates from that in the AFF one – as this indicates the exact moment in which negation begins to affect the real-time course of sentence interpretation.

The graphs in Figure 6.19 show the proportion of looks to the mentioned argument (i.e., the green triangle in (10)) after the Disambiguation Point, computed in the 50ms time-slots for controls (Fig. 6.19a-c) and dyslexics (Fig. 6.19d-f). From top to bottom, we have the conditions including one (a-d), two (b-e), and three (c-f) pictures of the mentioned argument. The affirmative condition (AFF) is plotted in blue: here, the picture of the mentioned argument represents the target of sentence (10). The negative condition (NEG) is plotted in red: here, the picture of the mentioned argument is the picture to avoid (i.e., the negated state of affairs). The horizontal axis shows the selected time period, and the time point 0-ms corresponds to the DisP onset. The vertical line indicates the beginning of the broad time-window identified in the previous analyses as our major area of interest.

(10) The triangle is/is not [DisP] green…

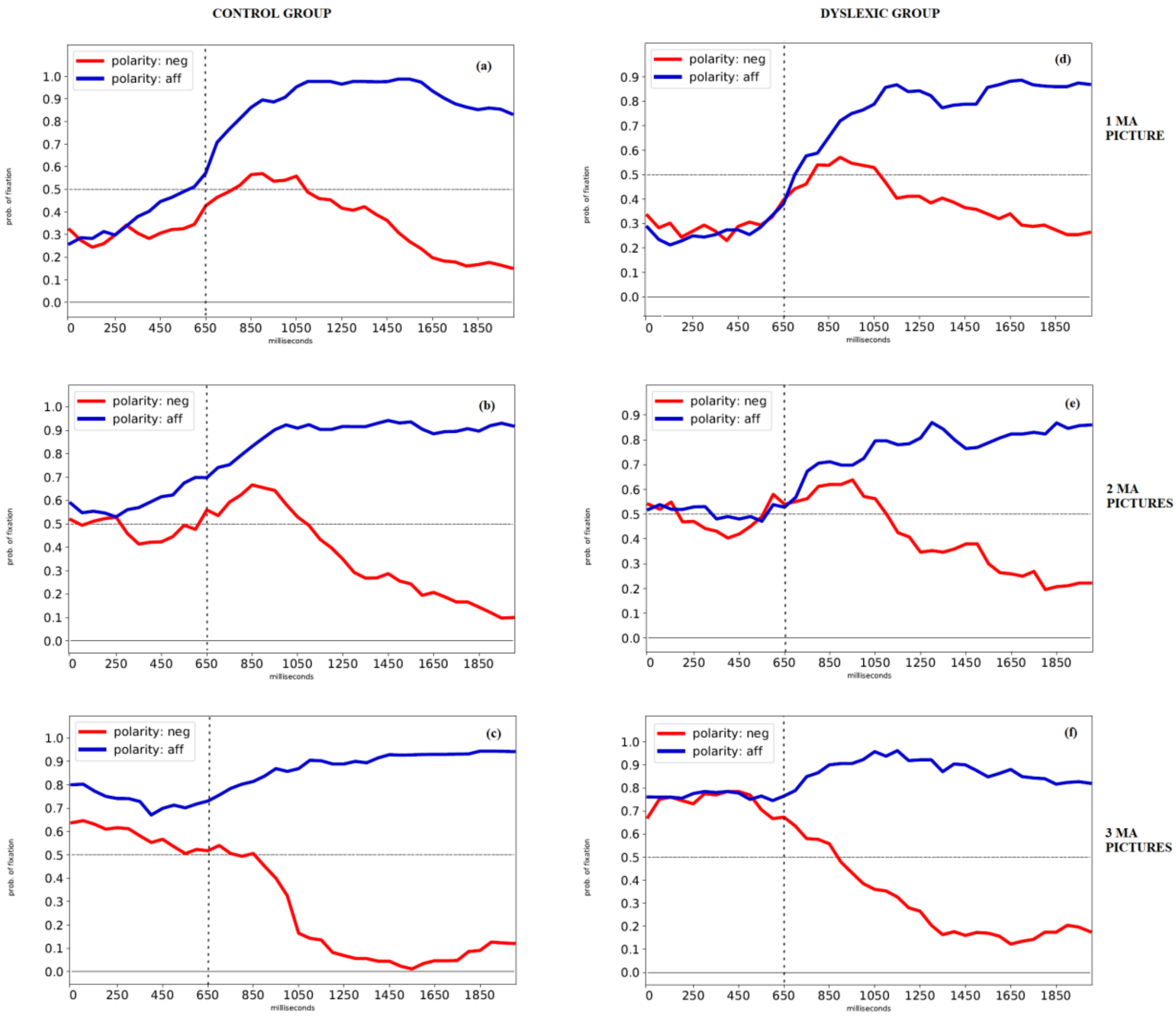

Figure 6.19. Proportion of looks to the mentioned argument (i.e., the green triangle in (10)) for controls (6.19a-c) and dyslexics (6.19d-f) including one (a-d), two (b-e), and three (c-f) pictures of the mentioned argument.

One mentioned argument. Graph (6.19a) and (6.19d) show the experimental condition including one picture of the mentioned argument: for the NEG condition, the visual scenario includes three potential targets. For dyslexics (6.19d), we see an initial pattern of MA fixations in both the AFF (blue line) and the NEG (red line) conditions for 300ms after the disambiguation offset. At this point (900ms in the graph), the red line started to decrease, indicating that dyslexics were shifting their visual attention towards the actual target of the negative sentence. A similar pattern of MA fixations can be observed for the control group (6.19a), with the two lines departing in different directions about 250ms after the disambiguation offset. However, we can see that controls were looking less steadily at the MA picture already during the unfolding of the critical word, as revealed by the fact that the two lines never overlap. Overall, this pattern of fixations reveals that, despite the high probability of target fixation in this experimental condition (.75), when presented with negative sentences both dyslexics and controls initially focused on the picture of the mentioned argument for about 300ms after the disambiguation offset. Worth noting, the former fixated the MA picture more steadily than the latter.

Two mentioned arguments. Graph (6.19b) and (6.19e) depict the experimental condition with two pictures of the mentioned argument: here, the visual scenario includes two potential targets for both AFF and NEG sentences. In the dyslexic group (6-19e), we see an initial increase of fixations towards the mentioned argument in both the AFF and the NEG conditions: 300ms after the disambiguation offset, the MA fixations started to decrease in the NEG one, indicating that the dyslexics' visual attention was drawn towards the actual referent of the negative sentence. In the control group (6.19b), we can notice a similar pattern: after an initial increase of MA fixations in both the AFF and the NEG conditions, the two lines depart in opposite directions about 250ms after the offset of the disambiguation. Altogether, the two groups showed a similar pattern of MA fixations in the NEG condition with two mentioned arguments. However, like in the condition with one MA, controls were fixating at the visual competitor less often than in the AFF baseline already before the disambiguation offset.

Three mentioned arguments. Graph (6.19c) and (6.19f) show the experimental condition including three pictures of the mentioned argument: for the NEG condition, the visual scene includes only one target picture. A visual inspection of the graphs reveals opposite patterns of MA fixations in the AFF and the NEG conditions after the disambiguation offset for both groups. This indicates that, despite the high base probability of MA fixations in this experimental condition (.75) both dyslexics and controls disambiguated the visual referent in the NEG condition very quickly. In the dyslexic group (6.19f), the red line (NEG) departs from the blue line (AFF) at 550ms in the graph, that is, during the unfolding of the critical word. In the control group (6.19c), the MA fixations in the NEG condition started to decrease at about 400ms after the disambiguation onset. All in all, a similar pattern of MA fixations in the NEG condition can be observed in the two groups, with participants shifting their gaze towards the actual target of the negative sentence already before the offset of the disambiguation. However, as observed in the other experimental conditions, controls were looking at the mentioned argument less steadily than in the AFF baseline compared to dyslexics. Furthermore, participants were significantly faster at identifying the actual target of the negative sentences compared to the condition with one and two MA pictures.

To conclude, these findings confirm the facilitating effect of the visual prominence of the mentioned argument on the interpretation process, with participants (both controls and dyslexics) being faster at identifying the visual referent of the negative sentence when more pictures of the mentioned argument (i.e., the competitors representing the negated situation) were displayed in the visual scene. Although similar patterns of fixations were reported for dyslexics and controls across experimental conditions, controls were always looking at the picture of the mentioned argument less steadily than in the AFF baseline before their attention converged towards the target picture. This suggests that dyslexics exploited the visual representation of the negated information more during the real-time processing of negative sentences.

Finally, the fact that participants' looking pattern behaviour in the AFF and the NEG conditions began to differ very early (within 300ms from the disambiguation offset) indicates that negation was processed very fast across the three experimental conditions. Note that very similar patterns of fixations towards the mentioned argument were also reported in the descriptive analysis with cartoon characters (§6.3.3.1): however, here participants took remarkably longer in shifting their visual attention from the mentioned argument towards the target of the NEG sentence. On the contrary, no facilitating effect of the visual prominence of the mentioned argument has been reported for black and white geometric shapes (§6.3.3.2), where the penalty carried by negation was constant throughout experimental conditions. This suggests some degree of flexibility and sensitivity of negation processing to propositional and perceptual features, which will be further discussed in §6.4.3

6.4 General discussion

In this section, we will present the major findings of this study. First, we will outline the main results of the behavioural and eye movement analyses: as we will see, they clearly indicate that dyslexics adopt a non-incremental strategy of negation processing exactly like controls. Then, in §6.4.2, we will provide compelling evidence that dyslexics are affected by a more general processing impairment, not limited to the computational cost of linguistic negation. On the basis of some differences and some common features that emerged from participants' looking pattern behaviour across item types, in §6.4.3 we will discuss how, and to what extent, the complexity of the linguistic and the visual input might affect negation processing. To conclude, in §6.4.4, some considerations will be made on the relationship between working memory capacity and participants' linguistic behaviour, providing some suggestions for future developments of this study.

6.4.1 Evidence for a common non-incremental strategy of negation processing for dyslexic and normal readers

The first question of this study was to see whether there were group differences, i.e., whether dyslexics resorted to a different interpretative strategy in the processing of negative sentences compared to controls. In §6.2.4, we predicted a similar pattern of fixations with negative sentences in the control and the dyslexic group, replicating the pattern of findings reported in our first experiment (§4.4): that is, a facilitating effect of the visual prominence of the mentioned argument on the interpretation process, resulting in a reduced penalty for target identification, compared to the affirmative baseline, as the number of pictures of the mentioned argument increased. A similar pattern of findings would provide compelling evidence that dyslexics too resorted to a non-incremental strategy of negation processing. Despite the small number of participants who took part in this study (9 dyslexics and 15 controls, respectively), the analyses of their looking pattern behaviour during the real-time comprehension of affirmative and negative sentences highlighted common processing patterns in adults with and without dyslexia.

First, we found that both dyslexics and controls were systematically slower in target identification when presented with negative sentences than with the corresponding affirmative ones, as demonstrated by lower target preference values in the three negative conditions compared to the affirmative baseline. The only exception is represented by the cartoon character condition with one potential target: here, the target picture was fixated at almost the same rate in both the affirmative and the negative condition by controls, whereas dyslexics were even faster in target identification when presented with the negative sentence. On the one hand, we assume that, taken individually, this result might be due to the limited number of subjects tested. On the other hand, it also suggests some degree of sensitivity of negation processing to the propositional and perceptual features of the presented stimuli, which will be further discussed in §6.4.3.

Second, the processing penalty conveyed by negation compared to the affirmative baseline increased with the number of target pictures displayed in the visual scenario. As we already discussed throughout this and earlier chapters (§6.1, §4.4.1), in the negative condition an increase in the number of potential targets corresponded to a decrease in the number of pictures of the mentioned argument: in fact, while the pictures of the mentioned argument were the visual referents of the verbal description in the affirmative condition, they were the visual competitors instead in the negative one, as they depicted the negated state of affairs. In other words, the pattern of findings described above reveals that, in the negative condition, both dyslexics and controls were faster in target identification when the visual scene included more possible competitors (i.e., more pictures of the mentioned argument) than when it included more potential targets of the verbal description. The visual prominence of the negated information had a positive effect on the processing of negative sentences, as revealed by a reduced penalty in target identification, compared to the affirmative baseline, at the increase in the number of pictures of the mentioned argument.

However, it should be mentioned that the eye movement analyses revealed some differences across item types. The facilitating effect of the visual prominence of the mentioned argument has been reported with coloured geometric shapes (§6.3.3.3) and cartoon characters (§6.3.3.1), but not with black and white geometric shapes (§6.3.3.2). In this last condition, we found, in fact, that the processing penalty carried by negation, compared to the affirmative baseline, was constant across the three experimental conditions including a different number of potential targets. In addition, this pattern of fixations was found for both dyslexics and controls. Interestingly, the behavioural data concerning response accuracy showed that participants were significantly less accurate in target identification with black and white geometric shapes (§6.3.2). Overall, we interpret this pattern of findings as evidence of a substantial difficulty experienced by all participants in the processing of geometric shapes across negative conditions. This is arguably related to the fact that black and white geometric shapes were perceptually less salient compared to the other item types: as a consequence, participants could not benefit from the visual prominence of the negated information as in the other item type conditions.

The descriptive analyses conducted on the mentioned argument confirmed that the higher processing costs reported for negative sentences compared to the affirmative baseline were attributable to an initial pattern of fixations towards the picture(s) of the mentioned argument occurring immediately after the offset of the critical word: as said, this indicates a delay in target identification for the negative condition, as the picture of the mentioned argument corresponded to the visual representation of the negated state of affairs described in the sentence. Negation seems therefore to be integrated at a later moment into sentence meaning, with both dyslexics and controls actively exploiting the visual representation of the mentioned argument during the early moments of sentence comprehension. Strikingly, this initial pattern of fixations towards the mentioned argument was reported for all the three item type conditions. Furthermore, we found that, with cartoon characters and coloured geometric shapes, both groups of participants were faster in shifting their gaze from the visual representation of the negated information towards the actual target of the negative sentence when more pictures of the mentioned argument were displayed in the visual scene. This provides further confirmation of the positive effect of the visual prominence of the negated information on the processing. Significantly, the fact that for black and white geometric shapes we found a systematic penalty carried by negation, and that this penalty is attributable to an initial pattern of fixations towards the mentioned argument, leads us to assume that the results reported for this item type condition are not at odds with the others, but they rather indicate some flexibility in the processing of negative sentences, arguably related to the type of linguistic and visual stimuli provided.

Summarizing, the eye movement data disclosed two main processing features underlying sentence interpretation for both dyslexic and control subjects. First, we reported compelling evidence that negative sentences displayed higher processing costs than the corresponding affirmatives also when an adequate context of utterance is provided: significantly, this processing penalty is attributable to an initial pattern of fixations towards the picture(s) of the mentioned argument reported in all the negative conditions including a different number of target pictures. Second, the visual prominence of the mentioned argument has been found to have a facilitating effect on negation processing with cartoon characters and coloured geometric shapes. Taken together, these findings replicated the results achieved in our first study (§4.4), providing further evidence of a non-incremental strategy of negation processing. Along the lines of the Two-Step Simulation Hypothesis (Kaup et al. 2007, see §2.2.1.3), the higher processing costs reported for negative sentences are attributable to the fact that the processing of negative sentences always involves first the retrieval/construction of one more mental simulation (i.e., the negated state of affairs) compared to that of the corresponding affirmatives. As mentioned, we found some processing differences across the different item types, which, however, are strongly in compliance with a non-incremental strategy of negation processing. For cartoon characters, we did not find a delay in target identification in the negative condition with one potential target: however, we reported a facilitating effect of the visual prominence of the negated information on the processing, as revealed by a greater delay in target identification, compared to the affirmative baseline, at the increase in the number of target pictures in the visual scene. For black and white geometric shapes, we did not find a positive effect of the visual prominence of the negated information on the processing of negative sentences, but we nonetheless attested a systematic penalty in target identification across all the negative conditions compared to the affirmative baseline, due to an initial pattern of fixations towards the mentioned argument.

Crucially, incremental models of negation processing (§2.2.2.1) cannot account for the systematic processing penalty displayed by negation in a supportive context of utterance, nor for the facilitating effect of the visual prominence of the negated information on the processing. Incremental accounts maintain, in fact, that the processing of negative sentences resembles that of the corresponding affirmative, with no need to necessarily represent the positive counterpart to access the semantic negative meaning when an adequate context of utterance is provided – as in the case of our experiment (Wason 1965; De Villiers & Flusberg 1975; Glenberg & Robertson 1999; Dale & Duran 2011; Nieuwland & Kuperberg 2008; Staab et al. 2008, see §2.2.2.1). In contrast, these two main findings strongly suggest that the processing of negative sentences involves more complex and partially different cognitive representations compared to that of affirmatives, as proposed by the Two-Step Simulation Hypothesis (Kaup et al. 2007).

So far, we have seen that our results provided compelling evidence that both dyslexics and controls adopted a non-incremental strategy of negation processing, by actively exploiting the visual representation of the negated information during the real-time comprehension of negative sentences.

Previous behavioural research dealing with the relationship between developmental dyslexia, working memory resources and negative sentence processing (§5.3), reported consistent evidence for a non-incremental view of negation processing, showing that negative sentences were more difficult to comprehend than the corresponding affirmatives for both dyslexic and normal readers (Scappini et al. 2015, Hu et al. 2018), and that, in more classical sentence-picture verification paradigms, the true negative condition was the most difficult to process (Vender & Delfitto 2010, Scappini et al. 2015, Hu et al. 2018). Throughout the discussion, we have seen that all these studies interpreted their results by assuming that dyslexics' processing difficulties were related to limitations in their working memory capacity, which would prevent them from accomplishing too demanding linguistic operations (*Working Memory Deficit Hypothesis* - McLoughlin et al. 1994, 2002). A two-stage based interpretation of negation is in fact particularly taxing in terms of computational resources, as it involves the retrieval/construction of two different simulations (i.e., the negated and the actual state of affairs), that must be momentarily maintained in short-term memory for a later comparison. This would overload dyslexics' limited working memory resources, by preventing them from successfully interpreting negative sentences.

In their EEG-ERP study, Scappini et al. (2015) argued that dyslexics would adopt alternative but less effective cognitive processes during negative sentence comprehension with the aim of reducing the considerable working memory load required for a non-incremental interpretation of negation. Strikingly, our findings openly go against this assumption: the analyses of the participants' looking pattern behaviour confirmed in fact that dyslexics and controls adopted the same interpretative strategy in the processing of negative sentences, as revealed by very similar patterns of target fixations reported across negative conditions for the two groups of subjects. Furthermore, the visual prominence of the mentioned argument had a positive effect on the interpretation process of negative sentences for dyslexics: it made easier the retrieval/activation of the negated information from the visual scene and its temporary maintenance in the short-term memory during negative sentence interpretation, without overloading their limited computational resources. The relationship between working memory limitations and sentence interpretation will be further addressed in section §6.4.4.

6.4.2 Negation is not the only source of difficulty for dyslexics: evidence of a generalized interpretative impairment

In our first study, we reported compelling evidence that the computation of negation is a significant source of difficulty for adults without dyslexia (§ 4.4.2): in line with the Two-Step Simulation Hypothesis (Kaup et al. 2007), we found that the higher processing costs traditionally attributed to negative sentences are determined by the need to retrieve the negated information, which must be activated and subsequently inhibited in order to grasp the sentence negative meaning. The results of this second study revealed that adults with dyslexia adopted the same non-incremental processing strategy for the interpretation of negative sentences, and benefited, in terms of processing costs, from a greater visual prominence of the negated information during sentence comprehension. However, it was also found that the processing impairment exhibited by dyslexics is not limited to the computation of negative sentences and/or completely attributable to the higher processing costs required for a two-stage based interpretation. Dyslexics had a significantly worse performance in the affirmative conditions too, lagging behind their peers in target identification regardless of the polarity of the sentence.

The second question of the present study was to see whether negation processing was specifically impaired in the dyslexic population or whether their underperformance was independent of sentence polarity. In this section, we discuss our results against those of previous studies that came to different conclusions on the topic (§5.3, §6.2.4).

Previous research provided conflicting evidence on whether negation constitutes a specific source of processing difficulty for individuals with developmental dyslexia. As a matter of fact, while Vender and Delfitto (2010) argued that dyslexics' interpretative difficulties can be completely traced back to the high computational demand of a non-incremental processing of negative sentences, Scappini et al. (2015) and Hu et al. (2018) reported evidence for a more generalized impairment affecting the comprehension of both affirmative and negative sentences, probably arising as a consequence of the complexity of the sentence-picture verification task (see §5.3 for a more detailed discussion).

In the present work, the behavioural data collected did not reveal a significant group difference in the reference resolution task: however, we could indeed observe a tendency for dyslexics to be generally less accurate than normal readers in target identification regardless of item type and sentence polarity. This seems to suggest a more general processing difficulty experienced by dyslexics when engaged in the reference resolution task which is not limited to the computation of linguistic negation. While at the moment these observations drawn from the behavioural data remain speculative in nature, it is interesting to note that the results from the eye movement analyses go in the same direction. As a matter of fact, the analysis of participants' looking pattern behaviour showed that, with coloured and black and white geometric shapes, dyslexics were overall slower than controls in target identification, as indicated by lower target preference values in both affirmative and negative conditions. For black and white geometric shapes (§ 6.3.3.2), in our area of interest[110], the proportion of looks to the target was always higher for controls than for dyslexics in all the experimental conditions: for instance, the target preference in affirmative conditions including one, two and three potential targets was .64, .72, .79 for the control group and .51, .62, .76 for the dyslexic one, respectively. Furthermore, concerning negative sentences, the descriptive analysis on the mentioned argument showed that dyslexics were slower than controls in shifting their gaze away from the picture(s) of the mentioned argument towards the actual referent of the negative sentence, providing further confirmation of an overall delay in target identification compared to controls. For coloured geometric shapes (§6.3.3.3), dyslexics displayed lower target preference values compared to controls in most of the experimental conditions. In particular, in the affirmative conditions including one and two potential targets, the absolute proportion of looks to the target was .78 for controls vs .62 for dyslexics in the former, and .81 for controls vs. 68 for dyslexics in the latter. Likewise, in the negative condition with one potential target, the target preference was .70 for controls but only .56 for dyslexics. In addition, dyslexics exploited more the visual representation of the negated information during real-time sentence comprehension than controls, as indicated by a steadier pattern of fixations towards the mentioned argument before their attention converged towards the target picture.

The fact that dyslexics were slower than controls in target identification, regardless of sentence polarity, is further corroborated by the absence of a significant interaction between group and polarity, which confirms that the penalty carried by the negative condition compared to the affirmative baseline was similar in the two groups of participants: for black and white geometric shapes, the difference in target preference values between AFF and NEG conditions was .19 for controls (.72 vs .53) and .18 for dyslexics (.63 vs .45); for coloured geometric shapes the difference was .18 for controls (.80 vs .62) and .16 for dyslexics (.72 vs .56). In other words, we did not find that dyslexics performed remarkably worse than controls in the negative condition compared to the affirmative baseline, as we would expect if dyslexics were impaired only in the computation of negative sentences.

Taken together, our findings indicate that dyslexics displayed an overall delay in target identification compared to controls with both affirmative and negative sentences, providing further confirmation to the results reported by Hu et al. (2018). Although negative sentences represented a source of difficulty for both groups of participants, in line with a non-incremental view of negation processing, dyslexic adults manifested a more general interpretative impairment affecting the overall sentence processing. On one hand, the visual prominence of the negated

[110] We identified as major area of interest the time-window from the offset of the critical word (650ms) to 1500ms after its offset (2150ms)

information improved dyslexics' performance, as confirmed by a reduced penalty in target identification for negative sentences compared to the affirmative baseline. On the other hand, however, dyslexics still displayed a delay in target identification compared to controls, that, crucially, has also been observed with affirmative sentences. Therefore, our results are not in compliance with Vender & Delfitto (2010), who proposed that dyslexics' interpretative difficulties with sentence interpretation were completely attributable to the computational cost of negation. Interestingly, Hu et al. (2018) did not exclude that the more general processing impairment exhibited by dyslexics could be caused by the interplay between dyslexics' working memory inefficiency and the task complexity: indeed, the sentence-picture evaluation required to accomplish the task introduces an additional processing cost, which might have a negative impact on the overall sentence comprehension process. The deployment of an identification task with eye-recording (§3.4, §3.5) has allowed us to assess the time-course of sentence comprehension without introducing an additional computational load which might bias the dyslexics' interpretative strategy. Strikingly, the same processing difficulties have been reported also with our experimental protocol: this provides compelling evidence that these interpretative difficulties in spoken language comprehension are related to specific aspects of the linguistic processing and are not attributable to an experimental artifact of the sentence-picture verification set-up.

To conclude, our results suggests that negation does not represent a specific source of processing difficulty for dyslexics. Rather, adults with dyslexia manifest a more general interpretative impairment compared to control subjects, which is only in part related to the high computational demand of a non-incremental processing of negation.

For the aim of the present discussion, it is worth noting that the analysis of participants' looking pattern behaviour with cartoon characters (§6.3.3.1) revealed that dyslexics did not exhibit specific processing difficulties compared to control subjects, as confirmed by very similar target preference values displayed by the two groups during real-time comprehension of both affirmative (.63 for controls vs .59 for dyslexics) and negative sentences (.51 for both). As we will see in the next section, this further suggests that the type of linguistic and visual stimuli provided do affect, at least to some extent, the sentence interpretative process.

6.4.3 Sensitivity to the complexity of the linguistic and the visual input: some considerations from the differences emerged across item types

The eye movement analyses showed a very similar pattern of fixations across the three item conditions for both dyslexics and controls, indicating that participants adopted the same processing strategy during the real-time interpretation of negative sentences. However, throughout the discussion, we have underlined some peculiarities emerged across the different item types, which suggest that the processing of sentential negation might be sensitive to the complexity of the linguistic and the visual input provided for both groups of participants.

In our first study, we observed that negative sentences were processed faster with coloured geometric shapes than with the other item types, as revealed by the fact that our (unimpaired) subjects disambiguated the target picture very quickly across all the negative conditions (§4.4.4). Interestingly, this finding was replicated in the present study for both groups (§6.3.3.3). The descriptive analysis on the mentioned argument revealed that participants' looking pattern behaviour in the affirmative and corresponding negative conditions began to differ very early (within 300ms after the offset of the disambiguation), regardless of the number of pictures of the mentioned argument displayed in the visual scene. This early deviation of the eye gaze pattern indicates that negation was quickly integrated into sentence meaning in all the three negative conditions. As discussed in chapter 4, we assume that negation was processed very fast with coloured geometric shapes because the linguistic input denoted a surface property (i.e., the colour) which was perceptually very salient. Moreover, the interpretation of colour adjectives is also remarkably easier than that of other adjectives from a propositional point of view[111]. Altogether, this made much easier the retrieval/activation and subsequent inhibition of the negated colour information from the visual scene during the interpretation process. However, if on one hand the perceptual salience of colours had a facilitating effect on the real-time integration of the visual and the linguistic information, on the other hand dyslexics were overall slower than controls in target identification in both the affirmative and the negative conditions. In particular, for negative sentences, in the previous section we have seen that dyslexics were always looking at the picture(s) of the mentioned argument more steadily than controls before their attention converged towards the target picture. This indicates that dyslexics exploited more the visual representation of the negated information during negative sentence comprehension.

All in all, colour adjectives seemed to have a facilitating effect on the interpretation process for both dyslexics and typical subjects, arguably due to their great perceptual saliency and their simple propositional content. This is in line with what observed with black and white geometric shapes (§6.3.3.2): here, the analysis of participants' looking pattern behaviour showed a constant penalty conveyed by negation, compared to the affirmative baseline, across the three negative conditions. This finding, reported for both controls and dyslexics, has been interpreted as

[111] The reader can refer to section §4.4.4 for a more in-depth discussion of how colour can be considered one of the guiding attributes of the visual attention, and for some notes on the easier interpretation of colour adjectives compared to other types of adjectives.

evidence of a considerable difficulty experienced by participants in the elaboration of uncoloured geometric shapes. Significantly, this item condition involved more abstract features of meaning, such as the presence or the absence of the described entities: this made the encoding of the linguistic information more complex than that required for perceptual features such as colours, also in terms of the mental representations involved in the interpretative process (see §4.4.4 for some considerations on the interpretative asymmetry of b/w geometric shapes with respect to the other item conditions). Furthermore, while colour had a facilitating effect on the interpretation process, as it made the retrieval of the negated information easier from the visual scene, black and white geometric shape were not perceptually very salient: as a consequence, participants could not benefit from the visual representation of the negated information during sentence interpretation as with the other item types. Again, in the negative conditions, dyslexics were slower than controls in shifting their gaze from the picture of the mentioned argument towards the actual referent of the verbal description.

Finally, two conclusions can be drawn from the analysis of participants' looking pattern behaviour with cartoon characters. First, in the condition including one potential target we did not find an advantage in target identification for the affirmative condition over the negative one in either group. Second, dyslexics' interpretative performance resembled that of controls with both affirmative and negative sentences. While the former outcome is likely related to the small number included in this follow-up study, the latter clearly suggests that this item type condition was the easiest one for dyslexics to process, as they did not face any specific difficulty in the accomplishment of the reference resolution task compared to controls. This observation is not trivial if we consider that this item condition seems to be the most complex, both from a linguistic and a perceptual perspective: the experimental sentences described different characters performing complex actions on/with common objects, and, as a consequence, the visual scenes were very rich in detail and colours. In this respect, our intuition is that dyslexics were facilitated when the mental representations involved in the comprehension process were related to more concrete and everyday scenes/actions, such as for instance cuddling an animal or riding a bike. This, together with the many perceptual details depicted in the visual scenario, might have prompted the real-time integration of the visual and the linguistic information during sentence comprehension. Instead, as we have seen with black and white geometric shapes, the low salience of the visual stimuli could have exacerbated the processing troubles for dyslexics.

Taken together, these findings reveal that the processing of sentential negation displayed some degree of flexibility and sensitivity to the propositional and perceptual features of the presented stimuli. Colour, which was simple and perceptually very salient, had a facilitating effect on the decoding for both dyslexics and controls. Conversely, cartoons characters and black and white geometric shapes items required a deeper evaluation, as their greater linguistic and visual complexity made the comprehension process more demanding. Remarkably, dyslexics relied more on the visual representation of the mentioned argument during sentence interpretation with coloured and black and white geometric shapes, compared to controls. Instead, no differences were attested between the two groups with cartoon characters, suggesting that visual scenes depicting more concrete and easily representable actions facilitated the sentence comprehension process for dyslexics.

Another possible explanation is that richer and more complex visual scenes might enhance dyslexics' performance, as they tend to rely more on the visual information during the processing, compared to controls, as a form of compensatory strategy for their interpretative impairments. This would account also for their difficulties with black and white geometric shapes that, as observed above and in Chapter 4, involved the computation of more abstract and hence complex features of meaning (i.e., non/existence of a specific object): while with the other item types the processing was facilitated because the relevant object was always visually represented in all the quadrants, the low visual saliency of black and white geometric shapes was not enough for dyslexics to compensate their language processing deficit.

6.4.4 Working memory impairments and sentence processing: where we stand and future research directions

In chapter 5, we have seen that previous studies dealing with the relationship between developmental dyslexia and the comprehension of negative sentences have interpreted their results by assuming that dyslexics' processing difficulties are due to the well-attested working memory impairments affecting this population, along the lines of the *Working Memory Deficit Hypothesis* (McLoughlin et al. 1994, 2002 - and its implementation by Vender 2011, 2017).

In the present study, we reported compelling evidence that dyslexic adults underperformed, compared to controls, in the real-time comprehension of both affirmative and negative sentences. We interpreted these results as evidence that dyslexics face some general processing difficulties during the online reference resolution task, which are not limited to the computational cost of linguistic negation. In line with previous research on the topic, this interpretative deficit could be attributed to dyslexics' limited verbal working memory, which is not efficient enough to cope with too cognitively demanding linguistic operations. This assumption is corroborated by the results of the working memory tests administered to the two groups of participants (§6.2.2.1), which confirmed significant phonological and central executive impairments in adult dyslexics compared to the age-matched controls (§6.3.1). However, regression and correlational analyses have not been included in this study given the reduced number of dyslexic participants:

further research is therefore needed to statistically assess the influence of working memory capacity on participants' linguistic behaviour.

In a future development of the present work, it would be therefore useful to: i) increase the number of participants (both dyslexics and controls) to seek confirmation of the preliminary findings reported here; ii) include a second group of younger control subjects (i.e., adolescents) to assess whether their performance is in line with that exhibited by adult dyslexics. The latter would provide further confirmation that dyslexics' interpretative behaviour is determined by underdeveloped processing abilities.

6.5 Concluding remarks

The goal of this follow-up study was two-fold: first, we aimed at understanding whether dyslexics adopted the same non-incremental strategy in the processing of negative sentences as controls, along the lines of the results achieved in our first study with unimpaired adult subjects; second, we questioned whether dyslexics underperformed compared to controls in sentence processing. If they did, the next question was to see whether negation was specifically impaired or whether their underperformance was independent of sentence polarity, pointing to a more general interpretative impairment.

In order to do so, we carried out an *identification task with eye recording* to compare the time course of sentence comprehension during the processing of affirmative and corresponding negative sentences. This methodology has allowed us to assess participants' final sentence comprehension without introducing an additional computational load (which might have biased dyslexics' interpretative strategy in previous studies): at the same time, the eye-recording provided us with unbiased fine-grained information on the ongoing cognitive processes underlying the time-course of negative sentence comprehension in the dyslexic and the control group. This, together with the manipulation of the visual prominence of the negated information across experimental conditions, has enabled us to answer our two main research questions:

i) do dyslexic adults adopt alternative processing strategies during negative sentence comprehension in comparison to controls?

The comparison of the participants' looking pattern behaviour disclosed common processing aspects underlying sentence comprehension between two groups. Compared to the affirmative baseline, both dyslexics and controls were always slower in target identification across negative conditions. In addition, the visual prominence of the negated information had a positive effect on the processing in two out of the three item conditions: when presented with cartoon characters and coloured geometric shapes, both groups were faster in shifting their gaze towards the actual target of the negative sentence as the number of pictures of the mentioned argument (i.e., the visual competitor corresponding to the negated information) increased. This indicates that negation was integrated later into sentence meaning, as revealed by an initial pattern of fixations towards the mentioned argument reported across negative conditions with all the item types.

Taken together, these results replicate the findings outlined in our first study and speak in favour of a non-incremental view of negation processing, following the Two-Step Simulation Hypothesis (Kaup et al. 2007). Strikingly, we found that dyslexics and controls adopted the same interpretative strategy during the processing of negative sentences, by actively exploiting the visual representation of the negated information (i.e., the mental simulation under construction) at the early stages of the processing.

ii) is negation a source of processing difficulty for dyslexics?

In line with a non-incremental view of negation processing, negative sentences represented a source of difficulty for both groups of participants, who benefited from the prominence of the negated information in the visual scene during the sentence interpretation process, as confirmed by a reduced penalty in target identification for the negative condition compared to the affirmative baseline. However, eye movement data revealed that dyslexics underperformed in target identification compared to controls with both affirmative and negative sentences in two out of the three item conditions.

This points to a more general interpretative impairment experienced by the dyslexic population, which seems to be only in part attributable to the higher processing cost required for a two-stage based computation of negation (a cost paid by controls too). Arguably, dyslexics' poor performance can be caused by their underdeveloped verbal working memory resources, which prevent them from accomplishing demanding linguistic operations in the same way as their age-matched control subjects.

To conclude, the eye movement analyses showed very similar pattern of fixations across the three item conditions for both dyslexics and controls, providing compelling evidence of a common non-incremental strategy of negation processing. It is worth noting, however, that minor differences emerged across item types, indicating some degree of sensitivity of negation processing to propositional and perceptual aspects of the presented stimuli. As for dyslexics, we found that: i) they relied more on the visual (negated) information during sentence comprehension compared to controls when presented with geometric shapes; ii) visual scenes depicting more concrete and easily representable actions, such as those employed for cartoon characters, seemed to facilitate dyslexics during the sentence comprehension process.

7 Conclusions

This chapter concludes the thesis. In section 7.1, we will recapitulate the theoretical background that motivated both our studies and brought about their specific research questions. Then, we will outline our main results and their theoretical implications. In section 7.2, we will address some limitations of the present experimental work providing suggestions for future research directions.

For ease of reading of this concluding section, bibliographical references have been omitted (where possible) and replaced with references to the related chapters' sections.

7.1 Theoretical implications of our main experimental findings

7.1.1 Study One

This thesis has largely focused on the broad theoretical debate on the processing of sentential negation (chapter 2). Despite sentential negation has been matter of a considerable amount of psycholinguistic research, two of the core aspects of its processing are under discussion: first, the time and the mode of negation integration into the semantic meaning of the sentence; second, the role played by the linguistic information occurring under the scope of negation during the sentence comprehension process.

Throughout the discussion, we have seen that the findings reported by more classical experimental paradigms of language comprehension (e.g., sentence-picture verification task) and neurolinguistic techniques (e.g., EEG-ERPs studies) have provided not conclusive, and also contradictory evidence in this respect. On the one hand, a number of studies have provided evidence in favour of a non-incremental strategy of negation processing (§2.2.1), along the lines of the Two-Step Simulation Hypothesis (Kaup et al. 2007, see 2.2.1.3). In this view, negation is not immediately integrated into sentence meaning as the interpretation of the negative statement would necessarily first undergo the evaluation of its positive counterpart: this additional computational step involved in the comprehension process determines the higher processing costs traditionally reported for negative sentences compared to the affirmative ones, which can be reduced, but not completely eliminated, by a pragmatically felicitous context of utterance (i.e., consistent with the negated information). On the other hand, a number of studies have provided opposite evidence, pointing to an early integration of negation into the sentence meaning (§2.2.2), exactly as it happens for non-negative words. In this incremental view of negation processing, the computation of negative sentences would completely resemble that of the corresponding affirmatives: the higher processing costs reported for negative sentences are merely the consequence of a pragmatically infelicitous context of utterance, and can therefore be completely eliminated. Further evidence for an incremental view of negation processing has been reported by neuro-imaging studies (§2.2.2.2) showing that negation induces an early inhibition of those sensory-motor brain areas activated by the corresponding affirmative statements.

In our first study (§4), we aimed to address these two core and widely-debated aspects of the processing. To this end, we decided to investigate negative sentence comprehension using the visual world paradigm (§3.1), an experimental methodology which employs the recording of participants' eye movement during different tasks of language comprehension. As discussed throughout chapter 3, the analysis of the participants' looking pattern behaviour can in fact provide extremely precise information on the real-time course of sentence comprehension, that cannot be grasped in more classical experimental methodology relying on offline measures of sentence comprehension (§3.4). Indeed, eye movement data can yield important insights on how the linguistic and visual sources of information (in particular the visual representation of the negated information) are exploited by the parser during the comprehension of affirmative and corresponding negative sentences. However, the visual world set-up is not free from methodological limitations, which, as we have discussed for the few previous studies on negation processing conducted using this paradigm (§3.3), can bias the listeners' looking pattern behaviour during the comprehension process as well as the result interpretation (§3.4).

Based on these considerations, we deployed an identification task with eye-recording (§4.1) to compare the time course of sentence comprehension during the processing of affirmative and corresponding negative sentences by 62 Italian-speaking adults. Innovatively, we decided to manipulate the visual prominence of the negated information (§3.5, §4.1) by varying the pictures corresponding to the negated information on the visual scene. This allowed us to control possible visual biases related to lexical and reference resolution process (§3.3, §3.4), and, at the same time, to answer our two main research questions.

RQ1 – What is the role of the negated information during the interpretation process of negative sentences?

AW1 – Our results (§4.3) indicate that, during the earliest moments of sentence comprehension, the visual representation of the negated information (i.e., the information occurring under the scope of negation) was actively exploited by the parser for the retrieval and subsequent activation of the corresponding mental simulation. Furthermore, the visual prominence of negated information (i.e., having more pictures depicting the negated state of affairs in the visual scene) enhanced the processing of negative sentences, as confirmed by reduced processing costs, compared to the affirmative baseline, at the increase in the number of pictures of the mentioned (negated) argument.

RQ2 – At what point in the comprehension process is negation integrated into the semantic meaning of the negative sentence?

AW2 – Our findings strongly suggest that negation was integrated only at a later moment into sentence meaning, as evidenced by initial pattern of fixations towards the negated information across all negative conditions. On one hand, as said, the visual prominence of the negated information reduced the processing costs for negative sentences compared to the baseline, indicating that negation was integrated faster into sentence meaning. On the other, the processing penalty displayed by negation could not be completely eliminated, although a supportive pragmatic context was provided.

Theoretical implications - These findings constitute clear evidence of a non-incremental strategy of negation processing, along the lines of what assumed by the Two-Step Simulation Hypothesis. First of all, we found that during the earliest moments of sentence comprehension, the visual representation of the negated information was actively exploited by the parser: this points to a later integration of negation into sentence meaning, with a first computational step in which the mental representation under construction is arguably that of the corresponding positive situation. Second, the visual prominence of the negated information was reported to have a facilitating effect on the interpretation process by reducing the processing penalty conveyed by negation compared to the affirmative baseline. This indicates that comprehenders did benefit from being presented with the picture of the negated state of affairs, providing further confirmation that the activation of this information plays a crucial (and positive) role in the interpretation process. Finally, we found that the higher processing costs could not be completely eliminated, although the visual prominence of the negated information had a positive effect on the computation. This further supports the assumption that the processing of negative sentences is inherently more demanding than that of the corresponding affirmatives due to the different (and more complex) nature of the mental representations involved.

7.1.2 Study Two

In the second part of the dissertation, we extended the investigation of the processing of sentential negation to adults with dyslexia. Among the different theories proposed to account for developmental dyslexia (§5.2), we adopted the theoretical framework of the *Working Memory Deficit* (McLoughlin et al. 1994, 2002; implemented in Vender 2011, 2017), which maintains that deficits in the phonological and central executive working memory components can be held responsible for the entire range of linguistic (and attentional) impairments shown by dyslexics (§5.1). Indeed, working memory deficits are widely attested in the dyslexic population, and significant correlations have been reported between these and the entire range of dyslexics' linguistic impairments (§5.1.1.4). The experimental literature dealing with the relationship between developmental dyslexia, working memory resources and negation processing is fairly recent (§5.2).

Throughout chapter 5, we have seen that these (few) studies provided consistent evidence for a non-incremental strategy of negation processing and argued that dyslexics' processing difficulties are related to limitations in their working memory capacity, which prevent them from accomplishing too demanding linguistic operations. Nonetheless, they provided controversial evidence on whether or not negation constitutes a specific source of this processing complexity for dyslexics (§5.3). Vender and Delfitto (2010) argued that dyslexic children have specific difficulties in interpreting negative sentences, and that this difficulty must be traced back to the high computational demand required for a two-stage based computation. Conversely, other scholars showed that dyslexic adults were impaired in sentence comprehension regardless of the polarity of the sentence, pointing to a more general processing impairment that might be related to the experimental complexity of the task adopted (Scappini et al. 2015; Hu et al. 2018). Furthermore, Scappini et al. (2015) put forward the hypothesis of alternative (though less effective) cognitive strategies employed by dyslexics to try to overcome the excessive working memory load required for a non-incremental computation of negation.

In our second study (§6), we aimed to disentangle the relationship between working memory resources, developmental dyslexia and negation processing by conducting a reduced version of our former eye-tracking experiment with a group of 9 Italian dyslexic adults and a group of 15 typically developed peers. This methodology allowed us to gather unbiased and fine-grained information on the cognitive processes underlying real-time interpretation of negative sentences in dyslexic and normal readers, and, at the same time, to understand whether the former adopt alternative strategies during sentence comprehension.

Based on our previous findings in chapter 4, and on the experimental literature discussed (§5.3, §5.4), our research questions were the following:

RQ1– Do dyslexic adopt the same non-incremental strategy in the processing of negative sentences as controls?

AW1 – The results (§6.3) replicated those of the former experiment, showing that both dyslexics and controls adopted a non-incremental strategy for the processing of negative sentences. This is exemplified by the fact that: i) negation systematically displayed higher processing costs compared to the corresponding affirmative baseline in both groups; ii) the visual prominence of the negated information had a facilitating effect on the computation for both dyslexics and controls, reducing (but not completely cancelling) the processing penalty conveyed by negation; iii) negation was integrated later into the sentence negative meaning, as revealed by initial pattern of fixations towards the picture of the negated information attested in both groups.

RQ2 – Is negation specifically impaired in developmental dyslexia?

AW2 – Both behavioural (§6.3.1, §6.3.2) and eye movement data (§6.3.3) indicate that dyslexics underperformed in target identification compared to controls with both affirmative and negative sentences. This points to a more general interpretative impairment experienced by dyslexics, which can only be partially related to the higher processing costs required for a non-incremental interpretation of the sentence negative meaning.

Theoretical implications – These findings are consistent with those of our former experiment, and show that dyslexics resorted to the same non-incremental strategy of negation processing as their control peers. As predicted by the Two-Step Simulation Hypothesis, negative sentences constituted a source of processing difficulty for the two groups of subjects, given the extra mental representation involved in the computation (i.e., the negated state of affairs). Like in the previous experiment, participants benefited, in terms of processing costs, from being visually presented with the negated information, as confirmed by a reduced penalty conveyed by negation, compared to the affirmative baseline, as this information became more salient in the visual context. Nonetheless, dyslexics' interpretative performance was still significantly worse than that of controls, and, crucially, this also held for the processing of affirmative sentences. Altogether, we argue that dyslexics' lower-than-normal performance can be attributed to their underdeveloped working memory resources, which prevented them from accomplishing demanding linguistic operations in the same way as their age-matched control subjects.

7.2 Limitations and future research directions

A first limitation of the present work is certainly represented by the type of linguistic structure investigated: namely, the expression of Italian sentential negation, in which the semantic negative meaning of the sentence is conveyed by the presence of the negative marker *non* placed in preverbal position (§1.2.4). In fact, although we employed three different types of linguistic (and visual) stimuli (e.g., *Aladdin is not opening the door; The triangle is not green; There is not a star*[112]), the experimental sentences were all declarative sentences with this syntactic configuration. As we have seen in chapter 1, Standard Italian is a *non-*

[112] The reader is referred to Appendix A for the list of the original test sentences in Italian

strict Negative Concord language that allows for other syntactic structures to express sentential negation, such as the combination of the preverbal marker and a neg-word in postverbal position (e.g., ***Non** ha telefonato a **nessuno***), or the simple use of a neg-word in canonical subject position (e.g., ***Nessuno** ha telefonato*). It would be very interesting to extend the scope of future research to include these forms of negation, in order to understand whether the processing of such negative structures also involves the initial evaluation of the corresponding positive situation. Further insights could come from adapting our experimental design to other languages, for a cross-linguistic comparison of the possible cognitive strategies underlying the interpretation of sentential negation.

Furthermore, throughout the discussion of the different accounts of negation processing (chapter 2), we have seen that the strongest criticism towards a later integration of negation into the semantic meaning of the sentence is represented by the neurolinguistic findings from the embodiment cognition research (§2.2.2.2): these studies have in fact shown that the sensory-motor brain areas are not activated during the computation of negative sentences (as instead for the corresponding affirmatives). As discussed in §4.4.3, this neuro-imaging evidence is hardly compatible with the findings from our experimental studies, in which we investigated more complex linguistic structures denoting performed actions/events, perceptual or existential properties of the described entities, as well as the role of contextual visual cues in the interpretation process. In contrast, neurolinguistic research has dealt only with limited sets of action-related verbs in singular person so far, presented without any linguistic or visual discourse context. An interesting direction for future research could be to employ our experimental set-up to investigate these simpler forms of linguistic negation, so as to see whether participants exploit, and to what extent, the visual information corresponding to the negated information – or if, conversely, we would find evidence compatible with the neurophysiological one, pointing to a very early inhibition of the negated information during the processing. Another possible future research development might be to employ neuro-imaging techniques with our experimental set-up as now.

To conclude, we comment on a limitation concerning the statistical analyses performed in the second study. Throughout the discussion, we have argued that the processing difficulties manifested by dyslexics are the result of important limitations in their working memory capacity, which prevent them from performing particularly demanding cognitive tasks. This assumption is supported by the Working Memory Capacity evaluation (§6.2.2.1), as it showed significant differences between dyslexics and controls, with the former performing below the normative values. Nonetheless, due to the limited number of participants, we did not perform regression and correlational analyses to seek statistical confirmation of the influence of the working memory capacity on their linguistic behaviour. As discussed in §6.4.4, one of the goals of future research is to extend the number of subjects tested in order to perform these statistical analyses and look for stronger evidence of the relation between working memory resources, dyslexia and negation/language processing.

Appendix A

Full set of experimental sentences included in one of the twelve lists of stimuli created using the Latin-square design (Experiment 1, §4.2.2).

Il cerchio non è blu e il triangolo è verde	*The circle is not blue and the triangle is green*
Aladdin bussa alla porta e Jasmine coccola una tigre	*Aladdin is knocking at the door and Jasmine is cuddling a tiger*
Paperino gioca a golf e Minnie prende gli addobbi	*Donald Duck is playing golf and Minnie Mouse is picking the decorations*
Il triangolo non è verde e il cerchio è rosso	*The triangle is not green and the circle is red*
Non c'è una stella ma un quadrato	*There is not a star but a square*
Bugs Bunny gioca a basket e Titti nuota nel mare	*Bugs Bunny is playing basketball and Tweety is swimming in the sea*
Lisa non prende una carota e Bart tira con la fionda	*Lisa is not picking a carrot and Bart is shooting with a slingshot*
C'è un triangolo e un pentagono	*There is a triangle and a pentagon*
Non c'è una stella ma un triangolo	*There is not a star but a triangle*
Jasmine riceve un regalo e Aladdin raccoglie un bastone	*Jasmine is receiving a gift and Aladdin is picking up a stick*
Il quadrato è nero e il cerchio è rosso	*The square is black and the circle is red*
Il triangolo è verde e il cerchio è blu	*The triangle is green and the circle is blue*
Pimpi rastrella le foglie e Winnie dipinge un quadro	*Piglet is raking leaves and Winnie is painting a picture*
Lisa non accarezza la pecora ma suona il sassofono	*Lisa is not petting the sheep but she is playing the saxophone*
Ariel non taglia la torta e Biancaneve accarezza gli animali	*Ariel is not cutting the cake and Snow White is petting the animals*

Il quadrato non è nero e il cerchio è blu	*The square is not black and the circle is blue*
Aladdin non vola sul tappeto ma raccoglie un bastone	*Aladdin is not flying on the carpet but he is picking up a stick*
C’è un pentagono e una stella	*There is a pentagon and a star*
Titti non si allaccia le scarpe ma apre l’ombrello	*Tweety is not tying her shoes but he is opening the umbrella*
Jasmine non nutre un uccellino ma dà una mela al cavallo	*Jasmine is not feeding a bird but she is giving an apple to the horse*
Il cerchio non è rosso e il triangolo è verde	*The circle is not red and the triangle is green*
Paperino acchiappa una farfalla e Minnie sforna una torna	*Donald Duck is catching a butterfly and Minnie Mouse is baking a cake*
C’è un cerchio e un pentagono	*There is a circle and a pentagon*
Biancaneve non siede sul pozzo ma va a cavallo	*Snow White is not sitting on the well but she is riding a horse*
Paperino non beve il cocktail ma solleva i pesi	*Donald Duck is not drinking a cocktail but he is lifting weights*
Il quadrato non è nero e il triangolo è verde	*The square is not black and the triangle is green*
Il cerchio è rosso e il quadrato è nero	*The circle is red and the square is black*
Bart nasconde i petardi e Lisa si mette un fiore in testa	*Bart is hiding the firecrackers and Lisa is putting a flower on her head*
Non c’è una stella	*There is not a star*
Biancaneve non raccoglie una chiave ma legge una lettera	*Snow White is not picking up a key but she is reading a letter*
Il quadrato è nero e il cerchio è blu	*The square is black and the circle is blue*
Il quadrato non è grigio e il cerchio è rosso	*The square is not grey and the circle is red*

Topolino non cucina l'hamburger e Paperina si spazzola i capelli	*Mickey Mouse is not cooking the hamburger and Daisy Duck is brushing her hair*
C'è un pentagono e un quadrato	*There is a pentagon and a square*
Lisa gioca con l'hula-hoop e Bart si veste da Babbo Natale	*Lisa is playing hula-hoop and Bart is dressing up as Santa Claus*
Il quadrato è nero e il triangolo è verde	*The square is black and the triangle is green*
Minnie fa surf e Paperino calcia il pallone	*Minnie Mouse is surfing and Donald Duck is kicking the ball*
Bart non indossa un turbante ma mangia il cioccolato	*Bart is not wearing a turban but he is eating chocolate*
C'è un triangolo	*There is a triangle*
Non c'è un cerchio ma un quadrato	*There is not a circle but a square*
Jerry non corre per strada e Tom fa un pupazzo di neve	*Jerry is not running in the street and Tom is making a snowman*
Il cerchio non è rosso e il quadrato è nero	*The circle is not red and the square is black*
Winnie non scava con la pala e Pimpi trova un quadrifoglio	*Winnie is not digging with the shovel and Piglet is finding a four-leaf clover*
Non c'è un cerchio ma una stella	*There is not a circle but a star*
C'è un quadrato e una stella	*There is a square and a star*
Non c'è un pentagono ma una stella	*There is not a pentagon but a star*
Bugs Bunny sale sulla scala e Titti apre l'ombrello	*Bugs Bunny is climbing the ladder and Tweety is opening the umbrella*
Il quadrato è nero	*The square is black*
Topolino accarezza il cane e Paperina suona i bonghi	*Mickey Mouse is petting the dog and Daisy Duck is playing the bongos*
C'è un pentagono	*There is a pentagon*
Non c'è un quadrato ma un pentagono	*There is not a square but a pentagon*
Jerry non gioca con lo yo-yo ma assaggia il formaggio	*Jerry is not playing with the yo-yo but he is tasting the cheese*

Titti guida la vespa e Bugs Bunny strappa il disegno	*Tweety is driving the Vespa and Bugs Bunny is tearing up the drawing*
Il quadrato è grigio	*The square is grey*
Jasmine si sistema i capelli e Aladdin impugna la spada	*Jasmine is fixing her hair and Aladdin is holding the sword*
Ariel trova una perla e Biancaneve accarezza gli animali	*Ariel is finding a pearl and Snow White is petting the animals*
Non c'è un cerchio ma un triangolo	*There is not a circle but a triangle*
C'è un cerchio e un quadrato	*There is a circle a and a square*
Biancaneve raccoglie una chiave e Ariel pesca uno scarpone	*Snow White is picking up a key and Ariel is fishing out a boot*
Il triangolo è giallo e il cerchio è blu	*The triangle is yellow and the circle is blue*
Non c'è un quadrato ma un pentagono	*There is not a square but a pentagon*
C'è un cerchio e un triangolo	*There is a circle and a triangle*
C'è un triangolo e una stella	*There is a triangle and a star*
Ariel siede sullo scoglio e Biancaneve legge una lettera	*Ariel is sitting on the rock and Snow White is reading a letter*
Il quadrato è grigio e il triangolo è verde	*The square is grey and the triangle is green*
Il quadrato non è grigio	*The square is not grey*
Non c'è un pentagono	*There is not a pentagon*
Minnie non suona le maracas e Paperino solleva i pesi	*Minnie Mouse is not playing maracas and Donald Duck is lifting weights*
Il triangolo è verde	*The triangle is green*
Il cerchio non è blu e il quadrato è nero	*The circle is not blue and the square is black*
Il cerchio è rosso	*The circle is red*
Non c'è un cerchio	*There is not a circle*
C'è una stella	*There is a star*

Titti prende il sole e Bugs Bunny appoggia la valigetta	*Tweety is sunbathing and Bugs Bunny is putting down his briefcase*
Il triangolo è giallo	*The triangle is yellow*
Il quadrato è grigio e il triangolo è giallo	*The square is grey and the triangle is yellow*
Tom accende una candela e Jerry cavalca un cavalluccio marino	*Tom is lighting a candle and Jerry is riding a seahorse*
Non c'è un cerchio ma un pentagono	*There is not a circle but a pentagon*
Il cerchio non è blu	*The circle is not blue*
Paperina non pattina sul ghiaccio ma si spazzola i capelli	*Daisy Duck is not skating on ice but she is brushing her hair*
C'è una stella e un cerchio	*There is a star and a circle*
Il triangolo non è giallo	*The triangle is not yellow*
Il quadrato non è grigio e il triangolo è giallo	*The square is not grey and the triangle is yellow*
Il cerchio è blu e il quadrato è grigio	*The circle is blue and the square is grey*
C'è una stella e un pentagono	*There is a star and a pentagon*
Non c'è un quadrato ma un cerchio	*There is not a square but a circle*
C'è un triangolo e un cerchio	*There is triangle and a circle*
Pimpi solleva una carota e Winnie si dondola sul cavallo	*Piglet is lifting a carrot and Winnie is swinging on the horse*
Topolino non accarezza il cane ma solleva la rana	*Mickey Mouse is not petting the dog but he is lifting the frog*
Il triangolo non è verde	*The triangle is not green*
Il quadrato non è nero	*The square is not black*
C'è una stella e un triangolo	*There is a star and a triangle*
Pimpi non soffia la girandola e Winnie si dondola sul cavallo	*Piglet is not blowing the pinwheel and Winnie is swinging on the horse*
Il triangolo è giallo e il quadrato è nero	*The triangle is yellow and the square is black*

Non c'è un triangolo ma un cerchio	*There is not a triangle but a circle*
Il cerchio non è rosso	*The circle is not red*
Il cerchio è rosso e il triangolo è verde	*The circle is red and the triangle is green*
Winnie suona il tamburo e Pimpi mangia l'anguria	*Winnie is playing the drum and Piglet is eating the watermelon*
Il triangolo non è verde e il quadrato è nero	*The triangle is not green and the square is black*
Non c'è una stella ma un cerchio	*There is not a star but a circle*
Lisa sposta i libri e Bart mangia il cioccolato	*Lisa is moving the books and Bart is eating chocolate*
Aladdin non gioca con la scimmia e Jasmine dà una mela al cavallo	*Aladdin is not playing with the monkey and Jasmine is giving an apple to the horse*
Il cerchio è rosso e il triangolo è giallo	*The circle is red and the triangle is yellow*
Non c'è un triangolo ma una stella	*There is not a triangle but a star*
C'è un quadrato e un cerchio	*There is a square and a circle*
Minnie va sulla giostra e Paperino si toglie il cappello	*Minnie Mouse is going on the merry-go-round and Donald Duck is taking off his hat*
Il cerchio non è blu e il triangolo è giallo	*The circle is not blue and the triangle is yellow*
Paperina scatta una foto e Topolino fa un picnic	*Daisy Duck is taking a picture and Mickey Mouse is having a picnic*
Non c'è un pentagono ma un triangolo	*There is not a pentagon but a triangle*
Bugs Bunny non mangia la carota ma strappa il disegno	*Bugs Bunny is not eating the carrot but he is tearing up the drawing*
Jerry corre per strada e Tom fa un pupazzo di neve	*Jerry is running in the street and Tom is making a snowman*
Paperina pattina sul ghiaccio e Topolino solleva la rana	*Daisy Duck is skating on ice and Mickey Mouse is lifting the door*

Tom non gioca con l’aquilone ma suona la fisarmonica	*Tom is not playing the kite but he is playing the accordion*
C’è una stella e un quadrato	*There is a star and a square*
Pimpi non abbraccia la zucca ma trova un quadrifoglio	*Piglet is not hugging the pumpkin but he is finding a four-leaf clover*
Minnie non fa surf ma sforna una torta	*Minnie Mouse is not surfing but she is baking a cake*
Non c’è un pentagono ma un quadrato	*There is not a pentagon but a square*
C’è un quadrato e un triangolo	*There is a square and a triangle*
Il quadrato è grigio e il cerchio è rosso	*The square is grey and the circle is red*
Tom prende una mela e Jerry costruisce un castello di sabbia	*Tom is grabbing an apple and Jerry is building a sandcastle*

Appendix B

Results of the GLMM analyses conducted on the time period 650ms-1650ms in Experiment 1 (§4.3). Other time-slots not included within this time period have been included only when relevant. DV = target preference; IV = sentence polarity; Random effects = item and subject

Table 4.1 – Cartoon characters, condition with one target picture

Time-slot	***β***	**z**	***p*-value**
650ms-700ms	0.04	0.23	.82
700ms-750ms	0.01	0.08	.93
750ms-800ms	-0.04	-0.24	.81
800ms-850ms	-0.20	-1.11	.27
850ms-900ms	-0.38	-2.12	.03
900ms-950ms	-0.55	-3.11	< .001
950ms-1000ms	-0.60	-3.42	< .001
1000ms-1050ms	-0.43	-2.45	.04
1050ms-1100ms	-0.35	-2.04	.04
1100ms-1150ms	-0.34	-1.99	.05
1150ms-1200ms	-0.36	-2.08	.04
1200ms-1250ms	-0.36	-2.15	.03
1250ms-1300ms	-0.36	-2.17	.03
1300ms-1350ms	-0.36	-2.17	.03
1350ms-1400ms	-0.36	-2.12	.03
1400ms-1450ms	-0.28	-1.64	.10
1450ms-1500ms	-0.19	-1.17	.24
1500ms-1550ms	-0.09	-0.56	.58
1550ms-1600ms	-0.01	-0.08	.94
1600ms-1650ms	0.00	0.00	1.00

Table 4.2 – Cartoon characters, condition with two target pictures

Time-slot	***β***	**z**	***p*-value**
650ms-700ms	-0.07	-0.45	.65
700ms-750ms	-0.09	-0.56	.58
750ms-800ms	-0.32	-1.99	.05
800ms-850ms	-0.34	-2.09	.04
850ms-900ms	-0.35	-2.17	.03
900ms-950ms	-0.44	-2.69	< .01
950ms-1000ms	-0.70	-4.21	< .001
1000ms-1050ms	-0.75	-4.54	< .001
1050ms-1100ms	-0.94	-5.58	< .001
1100ms-1150ms	-0.99	-5.85	< .001
1150ms-1200ms	-0.96	-5.67	< .001
1200ms-1250ms	-0.95	-5.68	< .001
1250ms-1300ms	-0.93	-5.61	< .001
1300ms-1350ms	-0.95	-5.64	< .001
1350ms-1400ms	-0.99	-5.67	< .001
1400ms-1450ms	-0.88	-4.90	< .001
1450ms-1500ms	-0.86	-4.81	< .001
1550ms-1600ms	-0.77	-4.30	< .001
1600ms-1650ms	-0.53	-2.96	< .001
1650ms-1700ms	-0.49	-2.63	.03
1700ms-1750ms	-0.46	-2.45	< .01
1750ms-1800ms	-0.48	-2.60	< .01
1800ms-1850ms	-0.52	-2.72	.03

Table 4.3 – Cartoon characters, condition with three target pictures

Time-slot	***β***	**z**	***p*-value**
650ms-700ms	-0.08	-0.43	.66
700ms-750ms	-0.20	-1.11	.27
750ms-800ms	-0.36	-2.09	.04
800ms-850ms	-0.49	-2.83	< .001
850ms-900ms	-0.67	-3.83	< .001
900ms-950ms	-0.79	-4.48	< .001
950ms-1000ms	-0.93	-5.21	< .001
1000ms-1050ms	-1.15	-6.39	< .001
1050ms-1100ms	-1.16	-6.31	< .001
1100ms-1150ms	-1.27	-6.79	< .001
1150ms-1200ms	-1.31	-7.04	< .001
1200ms-1250ms	-1.35	-7.09	< .001
1250ms-1300ms	-1.29	-6.80	< .001
1300ms-1350ms	-1.55	-7.98	< .001
1350ms-1400ms	-1.59	-8.18	< .001
1400ms-1450ms	-1.45	-7.63	< .001
1450ms-1500ms	-1.40	-7.15	< .001
1550ms-1600ms	-1.24	-6.43	< .001
1600ms-1650ms	-1.19	-6.15	< .001
1650ms-1700ms	-1.09	-5.61	< .001
1700ms-1750ms	-0.97	-4.81	< .001
1750ms-1800ms	-0.93	-4.52	< .001
1800ms-1850ms	-1.03	-4.81	< .001
1850ms-1900ms	-0.99	-4.31	< .001
1900ms-1950ms	-0.86	-3.65	< .001
1950ms-2000ms	-0.75	-3.11	< .01

Table 4.4 – Black and white geometric shapes, condition with one target picture

Time-slot	***β***	**z**	***p*-value**
650ms-700ms	-0.04	-0.26	.80
700ms-750ms	-0.24	-1.46	.14
750ms-800ms	-0.37	-2.28	.02
800ms-850ms	-0.47	-2.88	< .001
850ms-900ms	-0.63	-3.87	< .001
900ms-950ms	-0.76	-4.65	< .001
950ms-1000ms	-0.67	-4.15	< .001
1000ms-1050ms	-0.74	-4.56	< .001
1050ms-1100ms	-0.80	-4.86	< .001
1100ms-1150ms	-0.87	-5.30	< .001
1150ms-1200ms	-0.96	-5.87	< .001
1200ms-1250ms	-0.92	-5.55	< .001
1250ms-1300ms	-1.08	-6.24	< .001
1300ms-1350ms	-0.98	-5.72	< .001
1350ms-1400ms	-1.20	-6.65	< .001
1400ms-1450ms	-1.09	-6.09	< .001
1450ms-1500ms	-1.18	-6.19	< .001
1550ms-1600ms	-1.10	-5.72	< .001
1600ms-1650ms	-1.28	-6.31	< .001
1650ms-1700ms	-1.19	-5.84	< .001
1700ms-1750ms	-1.12	-5.42	< .001
1750ms-1800ms	-1.17	-5.31	< .001
1800ms-1850ms	-0.90	-4.17	< .001
1850ms-1900ms	-0.91	-4.09	< .001
1900ms-1950ms	-0.79	-3.40	< .001
1950ms-2000ms	-0.69	-2.91	.02

Table 4.5 – Black and white geometric shapes, condition with two target pictures

Time-slot	***β***	**z**	***p*-value**
650ms-700ms	-0.22	-1.41	.16
700ms-750ms	-0.36	-2.27	.02
750ms-800ms	-0.59	-3.68	< .001
800ms-850ms	-0.80	-4.87	< .001
850ms-900ms	-0.96	-5.77	< .001
900ms-950ms	-1.02	-6.28	< .001
950ms-1000ms	-1.29	-7.79	< .001
1000ms-1050ms	-1.27	-7.55	< .001
1050ms-1100ms	-1.29	-7.67	< .001
1100ms-1150ms	-1.28	-7.46	< .001
1150ms-1200ms	-1.12	-6.64	< .001
1200ms-1250ms	-1.05	-6.15	< .001
1250ms-1300ms	-1.03	-5.97	< .001
1300ms-1350ms	-1.02	-5.94	< .001
1350ms-1400ms	-0.94	-5.53	< .001
1400ms-1450ms	-0.97	-5.62	< .001
1450ms-1500ms	-0.97	-5.59	< .001
1550ms-1600ms	-0.97	-5.58	< .001
1600ms-1650ms	-0.96	-5.35	< .001
1650ms-1700ms	-0.96	-5.35	< .001
1700ms-1750ms	-0.90	-4.98	< .001
1750ms-1800ms	-0.85	-4.57	< .001
1800ms-1850ms	-0.73	-3.88	< .001
1850ms-1900ms	-0.86	-4.35	< .001
1900ms-1950ms	-0.81	-3.94	< .001
1950ms-2000ms	-0.80	-3.82	< .001

Table 4.6 – Black and white geometric shapes, condition with three target pictures

Time-slot	*β*	z	*p*-value
650ms-700ms	-0.44	-2.51	.02
700ms-750ms	-0.55	-3.14	< .001
750ms-800ms	-0.90	-5.18	< .001
800ms-850ms	-1.31	-7.30	< .001
850ms-900ms	-1.42	-8.00	< .001
900ms-950ms	-1.37	-7.70	< .001
950ms-1000ms	-1.56	-8.53	< .001
1000ms-1050ms	-1.57	-8.36	< .001
1050ms-1100ms	-1.54	-7.89	< .001
1100ms-1150ms	-1.43	-7.25	< .001
1150ms-1200ms	-1.22	-6.28	< .001
1200ms-1250ms	-1.22	-6.11	< .001
1250ms-1300ms	-1.20	-5.85	< .001
1300ms-1350ms	-1.28	-6.10	< .001
1350ms-1400ms	-1.24	-6.00	< .001
1400ms-1450ms	-1.07	-5.14	< .001
1450ms-1500ms	-0.87	-4.18	< .001
1550ms-1600ms	-0.88	-543.80	< .001
1600ms-1650ms	-0.91	-4.06	< .001
1650ms-1700ms	-0.97	-4.18	< .001
1700ms-1750ms	-1.20	-5.02	< .001
1750ms-1800ms	-1.16	-4.80	< .001
1800ms-1850ms	-1.05	-4.42	< .001
1850ms-1900ms	-0.94	-472.94	< .001
1900ms-1950ms	-0.73	-3.22	< .001
1950ms-2000ms	-0.65	-2.86	.02

Table 4.7 – Coloured geometric shapes, condition with one target picture

Time-slot	**β**	**z**	***p*-value**
550ms-600ms	-0.33	-2.11	.04
600ms-650ms	-0.54	-3.50	< .001
650ms-700ms	-0.78	-5.02	< .001
700ms-750ms	-0.98	-6.32	< .001
750ms-800ms	-1.02	-6.39	< .001
800ms-850ms	-1.10	-6.68	< .001
850ms-900ms	-1.29	-7.14	< .001
900ms-950ms	-1.26	-6.74	< .001
950ms-1000ms	-1.22	-6.26	< .001
1000ms-1050ms	-0.95	-4.71	< .001
1050ms-1100ms	-1.20	-5.34	< .001
1100ms-1150ms	-1.03	-4.36	< .001
1150ms-1200ms	-0.95	-3.89	< .001
1200ms-1250ms	-0.97	-3.81	< .001
1250ms-1300ms	-1.18	-4.26	< .001
1300ms-1350ms	-1.00	-3.53	< .001
1350ms-1400ms	-0.92	-3.21	< .001
1400ms-1450ms	-0.89	-3.04	< .001
1450ms-1500ms	-0.99	-3.14	< .001
1500ms-1550ms	-0.89	-2.95	< .001
1550ms-1600ms	-0.87	-2.79	< .001
1600ms-1650ms	-0.85	-2.65	< .001
1650ms-1700ms	-0.94	-2.87	< .001
1700ms-1750ms	-0.63	-1.96	.05
1750ms-1800ms	-0.50	- 1.75	.08

Table 4.8 – Coloured geometric shapes, condition with two target pictures

Time-slot	**β**	**z**	***p*-value**
650ms-700ms	-0.90	-5.62	< .001
700ms-750ms	-1.11	-6.84	< .001
750ms-800ms	-1.39	-8.02	< .001
800ms-850ms	-1.72	-9.08	< .001
850ms-900ms	-1.76	-9.16	< .001
900ms-950ms	-1.69	-8.57	< .001
950ms-1000ms	-1.59	-8.09	< .001
1000ms-1050ms	-1.50	-7.45	< .001
1050ms-1100ms	-1.34	-6.62	< .001
1100ms-1150ms	-1.41	-6.62	< .001
1150ms-1200ms	-1.33	-5.94	< .001
1200ms-1250ms	-1.35	-5.75	< .001
1250ms-1300ms	-1.15	-5.75	< .001
1300ms-1350ms	-0.98	-3.95	< .001
1350ms-1400ms	-0.78	-3.24	< .001
1400ms-1450ms	-0.57	-2.34	< .001
1450ms-1500ms	-0.90	-2.21	< .001
1500ms-1550ms	-0.53	-1.51	.02
1550ms-1600ms	-0.38	-2.36	.13
1600ms-1650ms	-0.62	-2.07	.02
1650ms-1700ms	-0.57	-1.68	.04
1700ms-1750ms	-0.46	-5.62	.09

Table 4.9 – Coloured geometric shapes, condition with three target pictures

Time-slot	β	z	*p*-value
500ms-550ms	-0.31	-1.88	.06
550ms-600ms	-0.40	-2.44	.01
600ms-650ms	-0.63	-3.83	< .001
650ms-700ms	-0.86	-5.10	< .001
700ms-750ms	-1.02	-6.06	< .001
750ms-800ms	-1.16	-6.56	< .001
800ms-850ms	-1.42	-7.92	< .001
850ms-900ms	-1.54	-8.18	< .001
900ms-950ms	-1.56	-8.03	< .001
950ms-1000ms	-1.53	-7.69	< .001
1000ms-1050ms	-1.61	-7.88	< .001
1050ms-1100ms	-1.62	-7.67	< .001
1100ms-1150ms	-1.52	-7.08	< .001
1150ms-1200ms	-1.43	-6.54	< .001
1200ms-1250ms	-1.47	-6.53	< .001
1250ms-1300ms	-1.37	-5.89	< .001
1300ms-1350ms	-1.44	-5.76	< .001
1350ms-1400ms	-1.31	-5.22	< .001
1400ms-1450ms	-1.10	-4.51	< .001
1450ms-1500ms	-0.98	-3.92	< .001
1500ms-1550ms	-0.81	-3.12	< .001
1550ms-1600ms	-0.65	-2.47	.01
1600ms-1650ms	-0.56	-2.06	.04
1650ms-1700ms	-0.49	-1.86	.06
1700ms-1750ms	-0.82	-2.95	< .001
1750ms-1800ms	-0.68	-2.39	.02
1800ms-1850ms	-0.58	-2.02	.04

Results of the GLMM analyses conducted on the time period 650ms-15o0ms in Experiment 1 (§4.3). Other time-slots not included within this time period have been included only when relevant. DV = Mentioned Argument (MA) preference; IV = sentence polarity; Random effects = item and subject

Table 4.10 – Cartoon characters, condition with one MA picture

Time-slot	**β**	**z**	***p*-value**
650ms-700ms	0.04	0.25	.81
700ms-750ms	0.12	0.86	.39
750ms-800ms	0.05	0.37	.71
800ms-850ms	-0.01	-0.04	.97
850ms-900ms	-0.14	-1.01	.31
900ms-950ms	-0.15	-1.12	.26
950ms-1000ms	-0.10	-0.75	.45
1000ms-1050ms	-0.14	-1.00	.32
1050ms-1100ms	-0.22	-1.58	.29
1100ms-1150ms	-0.35	-2.58	.21
1150ms-1200ms	-0.42	-3.09	< .001
1200ms-1250ms	-0.50	-3.68	< .001
1250ms-1300ms	-0.55	-4.12	< .001
1300ms-1350ms	-0.63	-4.68	< .001
1350ms-1400ms	-0.63	-4.67	< .001
1400ms-1450ms	-0.72	-5.28	< .001
1450ms-1500ms	-0.83	-6.04	< .001

Table 4.11 – Cartoon characters, condition with two MA pictures

Time-slot	**β**	**z**	***p*-value**
650ms-700ms	-0.22	-1.64	.74
700ms-750ms	-0.23	-1.78	.36
750ms-800ms	-0.24	-1.81	.07
800ms-850ms	-0.25	-1.90	.07
850ms-900ms	-0.36	-2.65	.06
900ms-950ms	-0.45	-3.32	< .001
950ms-1000ms	-0.40	-2.92	< .001
1000ms-1050ms	-0.55	-3.92	< .001
1050ms-1100ms	-0.61	-4.40	< .001
1100ms-1150ms	-0.80	-5.65	< .001
1150ms-1200ms	-0.89	-6.39	< .001
1200ms-1250ms	-1.05	-7.39	< .001
1250ms-1300ms	-1.13	-7.77	< .001
1300ms-1350ms	-1.23	-8.44	< .001
1350ms-1400ms	-1.32	-9.01	< .001
1400ms-1450ms	-1.48	-10.08	< .001
1450ms-1500ms	-1.63	-10.87	< .001

Table 4.12 – Cartoon characters, condition with three MA pictures

Time-slot	β	z	*p*-value
650ms-700ms	0.06	0.41	.68
700ms-750ms	-0.02	-0.11	.92
750ms-800ms	-0.05	-0.32	.75
800ms-850ms	-0.12	-0.84	.40
850ms-900ms	-0.25	-1.67	.10
900ms-950ms	-0.36	-2.49	< .05
950ms-1000ms	-0.81	-5.26	< .001
1000ms-1050ms	-0.83	-5.31	< .001
1050ms-1100ms	-0.94	-5.96	< .001
1100ms-1150ms	-1.17	-7.20	< .001
1150ms-1200ms	-1.26	-7.74	< .001
1200ms-1250ms	-1.36	-8.39	< .001
1250ms-1300ms	-1.53	-9.19	< .001
1300ms-1350ms	-1.62	-9.46	< .001
1350ms-1400ms	-1.64	-9.67	< .001
1400ms-1450ms	-1.85	-10.50	< .001
1450ms-1500ms	-1.92	-10.97	< .001

Table 4.13 – Black and white geometric shapes, condition with one MA picture

Time-slot	**β**	**z**	***p*-value**
650ms-700ms	0.00	-0.02	.99
700ms-750ms	-0.13	-0.77	.44
750ms-800ms	-0.05	-0.31	.76
800ms-850ms	0.11	0.69	.49
850ms-900ms	0.09	0.55	.58
900ms-950ms	-0.12	-0.75	.45
950ms-1000ms	-0.11	-0.72	.47
1000ms-1050ms	-0.30	-1.91	.06
1050ms-1100ms	-0.54	-3.41	< .001
1100ms-1150ms	-0.92	-5.78	< .001
1150ms-1200ms	-1.23	-7.59	< .001
1200ms-1250ms	-1.50	-8.94	< .001
1250ms-1300ms	-1.73	-10.11	< .001
1300ms-1350ms	-1.93	-10.67	< .001
1350ms-1400ms	-2.30	-11.60	< .001
1400ms-1450ms	-2.39	-12.06	< .001
1450ms-1500ms	-2.71	-13.20	< .001

Table 4.14 – Black and white geometric shapes, condition with two MA pictures

Time-slot	**β**	**z**	***p*-value**
650ms-700ms	-0.18	-1.12	.26
700ms-750ms	-0.20	-1.27	.20
750ms-800ms	-0.19	-1.19	.23
800ms-850ms	-0.22	-1.36	.17
850ms-900ms	-0.41	-2.48	.02
900ms-950ms	-0.56	-3.39	< .001
950ms-1000ms	-0.72	-4.25	< .001
1000ms-1050ms	-0.79	-4.61	< .001
1050ms-1100ms	-0.76	-4.44	< .001
1100ms-1150ms	-1.03	-6.05	< .001
1150ms-1200ms	-0.97	-5.76	< .001
1200ms-1250ms	-1.16	-6.85	< .001
1250ms-1300ms	-1.20	-6.97	< .001
1300ms-1350ms	-1.30	-7.52	< .001
1350ms-1400ms	-1.22	-7.19	< .001
1400ms-1450ms	-1.27	-7.47	< .001
1450ms-1500ms	-1.38	-7.91	< .001

Table 4.15 – Black and white geometric shapes, condition with three MA pictures

Time-slot	β	z	*p*-value
550ms-600ms	-0.33	-1.89	.06
600ms-650ms	-0.35	-1.99	.05
650ms-700ms	-0.40	-2.28	.02
700ms-750ms	-0.45	-2.53	.02
750ms-800ms	-0.62	-3.41	< .001
800ms-850ms	-0.78	-4.22	< .001
850ms-900ms	-0.74	-4.06	< .001
900ms-950ms	-0.78	-4.20	< .001
950ms-1000ms	-1.06	-5.58	< .001
1000ms-1050ms	-1.23	-6.27	< .001
1050ms-1100ms	-1.36	-6.83	< .001
1100ms-1150ms	-1.62	-8.12	< .001
1150ms-1200ms	-1.58	-8.17	< .001
1200ms-1250ms	-1.90	-9.38	< .001
1250ms-1300ms	-2.01	-9.68	< .001
1300ms-1350ms	-2.32	-10.78	< .001
1350ms-1400ms	-2.30	-11.12	< .001
1400ms-1450ms	-2.29	-11.15	< .001
1450ms-1500ms	-2.48	-11.56	< .001

Table 4.16 – Coloured geometric shapes, condition with one MA picture

Time-slot	**β**	**z**	***p*-value**
600ms-650ms	-0.27	-1.76	.08
650ms-700ms	-0.55	-3.53	< .001
700ms-750ms	-0.80	-5.11	< .001
750ms-800ms	-1.11	-6.70	< .001
800ms-850ms	-1.24	-7.16	< .001
850ms-900ms	-1.84	-9.67	< .001
900ms-950ms	-2.20	-10.96	< .001
950ms-1000ms	-2.49	-11.74	< .001
1000ms-1050ms	-2.46	-11.79	< .001
1050ms-1100ms	-2.90	-12.57	< .001
1100ms-1150ms	-3.25	-13.23	< .001
1150ms-1200ms	-3.40	-13.71	< .001
1200ms-1250ms	-3.59	-13.81	< .001
1250ms-1300ms	-3.96	-13.79	< .001
1300ms-1350ms	-4.12	-14.00	< .001
1350ms-1400ms	-4.25	-14.19	< .001
1400ms-1450ms	-4.51	-14.10	< .001
1450ms-1500ms	-4.87	-13.61	< .001

Table 4.17 – Coloured geometric shapes, condition with two MA pictures

Time-slot	**β**	**z**	***p*-value**
650ms-700ms	-0.08	-0.50	.06
700ms-750ms	-0.42	-2.68	< .01
750ms-800ms	-0.69	-4.31	< .001
800ms-850ms	-1.00	-5.82	< .001
850ms-900ms	-1.47	-7.83	< .001
900ms-950ms	-1.54	-8.11	< .001
950ms-1000ms	-1.81	-9.33	< .001
1000ms-1050ms	-2.08	-10.58	< .001
1050ms-1100ms	-2.39	-11.35	< .001
1100ms-1150ms	-2.59	-12.20	< .001
1150ms-1200ms	-2.84	-12.82	< .001
1200ms-1250ms	-3.29	-13.56	< .001
1250ms-1300ms	-3.59	-13.53	< .001
1300ms-1350ms	-3.70	-13.42	< .001
1350ms-1400ms	-3.96	-13.37	< .001
1400ms-1450ms	-3.97	-15.30	< .001
1450ms-1500ms	-4.04	-15.47	< .001

Table 4.18 – Coloured geometric shapes, condition with three MA pictures

Time-slot	**β**	**z**	***p*-value**
600ms-650ms	-0.34	-2.10	.04
650ms-700ms	-0.59	-3.52	< .001
700ms-750ms	-0.81	-4.77	< .001
750ms-800ms	-1.18	-6.74	< .001
800ms-850ms	-1.49	-8.33	< .001
850ms-900ms	-2.04	-10.36	< .001
900ms-950ms	-2.47	-11.61	< .001
950ms-1000ms	-2.77	-12.49	< .001
1000ms-1050ms	-3.28	-13.16	< .001
1050ms-1100ms	-3.41	-13.62	< .001
1100ms-1150ms	-3.84	-14.41	< .001
1150ms-1200ms	-4.08	-14.59	< .001
1200ms-1250ms	-4.41	-14.31	< .001
1250ms-1300ms	-4.61	-14.13	< .001
1300ms-1350ms	-5.11	-13.72	< .001
1350ms-1400ms	-5.16	-12.79	< .001
1400ms-1450ms	-4.98	-12.65	< .001
1450ms-1500ms	-4.88	-12.37	< .001

Appendix C

Results of the GLMM analyses conducted on the time period 650ms-2150ms for the control and the dyslexic group in Experiment 2 (§6.3). DV = target preference; IV = sentence polarity; Random effects = item and subject

Table 6.1 – Cartoon characters, condition with one target picture

	Control group			**Dyslexic group**		
Time-window	***β***	**z**	**p-value**	***β***	**z**	***p*-value**
650ms-700ms	0.15	0.43	.67	0.29	0.62	.53
700ms-750ms	0.29	0.84	.40	0.39	0.88	.38
750ms-800ms	0.32	0.93	.35	0.34	0.78	.44
800ms-850ms	0.37	1.08	.28	0.52	1.21	.23
850ms-900ms	0.25	0.73	.46	0.41	0.97	.33
900ms-950ms	-0.03	-0.08	.94	0.36	0.84	.40
950ms-1000ms	-0.22	-0.69	.49	0.42	0.99	.32
1000ms-1050ms	-0.11	-0.33	.74	0.32	0.75	.45
1050ms-1100ms	-0.23	-0.70	.48	0.45	0.91	.36
1100ms-1150ms	-0.26	-0.71	.48	0.54	211.51	< .001
1150ms-1200ms	0.09	0.23	.81	0.32	0.47	.64
1200ms-1250ms	0.12	0.34	.73	0.07	0.13	.90
1250ms-1300ms	-0.09	-0.25	.80	-0.18	-0.34	.73
1300ms-1350ms	-0.02	-0.07	.94	-0.13	-0.24	.81
1350ms-1400ms	-0.01	-0.02	.98	0.24	0.48	.63
1400ms-1450ms	-0.14	-0.40	.69	0.24	0.46	.64
1450ms-1500ms	-0.28	-0.71	.48	0.41	0.67	.50
1500ms-1550ms	-0.19	-0.51	.61	0.49	0.99	.32
1550ms-1600ms	-0.15	-0.43	.66	0.44	0.91	.36
1600ms-1650ms	-0.06	-0.18	.86	0.39	0.79	.43
1650ms-1700ms	0.23	0.66	.51	0.36	0.89	.37

	Control group			Dyslexic group		
Time-window	***β***	**z**	**p-value**	***β***	**z**	***p*-value**
1700ms-1750ms	0.20	0.56	.57	0.32	0.80	.42
1750ms-1800ms	0.02	0.07	.95	0.36	0.88	.38
1800ms-1850ms	0.13	0.36	.72	0.51	1.22	.22
1850ms-1900ms	-0.04	-0.11	.91	0.49	1.15	.25
1900ms-1950ms	-0.20	-0.48	.63	0.16	0.37	.71
1950ms-2000ms	-0.52	-1.13	.26	0.27	0.61	.54
2000ms-2050ms	-0.22	-0.54	.59	0.25	0.58	.56
2050ms-2100ms	0.37	0.81	.42	0.21	0.47	.64
2100ms-2150ms	0.82	1.74	.08	-0.52	-1.11	.26

Table 6.2 – Cartoon characters, condition with two target pictures

	Control group			**Dyslexic group**		
Time-window	***β***	**z**	**p-value**	***β***	**z**	***p*-value**
650ms-700ms	-0.16	-0.50	.62	-0.07	-0.14	.89
700ms-750ms	-0.41	-1.29	.20	-0.12	-0.26	.79
750ms-800ms	-0.30	-0.97	.33	-0.29	-0.68	.50
800ms-850ms	-0.32	-1.01	.31	-0.20	-0.49	.62
850ms-900ms	-0.52	-1.67	.10	-0.33	-0.80	.42
900ms-950ms	-0.68	-2.21	.03	-0.35	-0.88	.38
950ms-1000ms	-0.72	-2.30	.02	-0.56	-1.37	.17
1000ms-1050ms	-1.20	-3.39	< .001	-0.66	-1.56	.12
1050ms-1100ms	-0.91	-2.63	< .01	-0.90	-2.18	.03
1100ms-1150ms	-1.05	-3.06	< .001	-1.16	-2.82	< .001
1150ms-1200ms	-1.09	-3.19	< .001	-0.95	-2.29	.02
1200ms-1250ms	-1.18	-3.50	< .001	-1.03	-2.48	< .01
1250ms-1300ms	-1.28	-3.75	< .001	-1.21	-2.92	< .001
1300ms-1350ms	-1.40	-3.99	< .001	-1.21	-2.39	.02
1350ms-1400ms	-1.35	-3.96	< .001	-1.05	-2.24	.03
1400ms-1450ms	-1.71	-4.72	< .001	-0.83	-1.76	.08
1450ms-1500ms	-1.83	-5.15	< .001	-1.32	-2.24	.03
1500ms-1550ms	-1.46	-4.14	< .001	-0.91	-2.12	.03
1550ms-1600ms	-1.56	-4.16	< .001	-1.18	-2.70	< .01
1600ms-1650ms	-1.39	-3.49	< .001	-1.02	-2.17	.03
1650ms-1700ms	-1.39	-3.30	< .001	-0.53	-1.22	.22
1700ms-1750ms	-1.48	-3.29	< .001	-0.39	-0.93	.35
1750ms-1800ms	-1.60	-3.60	< .001	-0.85	-1.79	.07
1800ms-1850ms	-1.73	-4.06	< .001	-0.57	-212.41	< .001
1850ms-1900ms	-1.71	-4.06	< .001	-0.41	-0.82	.41
1900ms-1950ms	-1.66	-552.80	< .001	-0.58	-1.16	.25

	Control group			Dyslexic group		
Time-window	***β***	**z**	**p-value**	***β***	**z**	***p*-value**
1950ms-2000ms	-2.10	-4.31	< .001	-0.24	-0.53	.60
2000ms-2050ms	-1.70	-3.59	< .001	-0.47	-0.94	.35
2050ms-2100ms	-2.20	-3.69	< .001	-0.43	-0.67	.51
2100ms-2150ms	-2.12	-3.78	< .001	-0.54	-0.80	.42

Table 6.3 – Cartoon characters, condition with three target pictures

	Control group			Dyslexic group		
Time-window	***β***	**z**	**p-value**	***β***	**z**	***p*-value**
650ms-700ms	0.19	0.53	.59	-0.98	-1.93	.05
700ms-750ms	-0.12	-0.36	.72	-1.11	-2.22	.03
750ms-800ms	-0.44	-1.19	.24	-1.16	-2.35	.02
800ms-850ms	-0.44	-1.25	.21	-1.70	-2.96	< .001
850ms-900ms	-0.48	-1.32	.19	-1.10	-2.19	.03
900ms-950ms	-0.55	-1.43	.15	-1.07	-2.24	.02
950ms-1000ms	-0.57	-1.58	.11	-1.18	-2.46	< .01
1000ms-1050ms	-0.52	-1.52	.13	-1.07	-2.23	.03
1050ms-1100ms	-0.75	-1.98	< .05	-1.16	-2.48	< .01
1100ms-1150ms	-1.22	-3.57	< .001	-2< .01	-3.38	< .001
1150ms-1200ms	-1.58	-4.31	< .001	-2.36	-3.56	< .001
1200ms-1250ms	-1.93	-4.66	< .001	-2.25	-3.61	< .001
1250ms-1300ms	-2.35	-5.45	< .001	-1.74	-3.03	< .001
1300ms-1350ms	-2.44	-5.60	< .001	-1.49	-2.87	< .001
1350ms-1400ms	-2.30	-5.39	< .001	-1.45	-2.56	< .01
1400ms-1450ms	-2.42	-5.34	< .001	-1.43	-2.37	.02
1450ms-1500ms	-2.28	-5.01	< .001	-1.73	-2.39	.02
1500ms-1550ms	-2.58	-5.16	< .001	-1.65	-2.34	.02
1550ms-1600ms	-2.64	-5.26	< .001	-0.99	-1.60	.11
1600ms-1650ms	-2.63	-4.96	< .001	-0.71	-1.16	.24
1650ms-1700ms	-2.76	-519.29	< .001	-0.87	-1.69	.09
1700ms-1750ms	-2.85	-5.27	< .001	-0.30	-0.60	.55
1750ms-1800ms	-2.72	-4.99	< .001	-0.22	-0.45	.65
1800ms-1850ms	-2.79	-4.81	< .001	-0.55	-1.08	.28
1850ms-1900ms	-2.44	-4.72	< .001	-0.45	-0.85	.39
1900ms-1950ms	-2.50	-4.62	< .001	-0.19	-0.32	.75

1950ms-2000ms	-2.59	-4.54	< .001	-0.37	-0.59	.55
2000ms-2050ms	-2.74	-4.57	< .001	-0.89	-1.19	.24
2050ms-2100ms	-3.04	-4.40	< .001	-0.75	-1.19	.23
2100ms-2150ms	-3.07	-4.11	< .001	-0.40	-0.63	.53

Table 6.4 – Black and white geometric shapes, condition with one target picture

	Control group			Dyslexic group		
Time-window	***β***	**z**	**p-value**	***β***	**z**	***p*-value**
650ms-700ms	-0.37	-1.06	.29	0.06	0.16	.87
700ms-750ms	-0.32	-0.90	.37	-0.09	-0.23	.82
750ms-800ms	-0.81	-375.40	< .001	-0.51	-1.25	.21
800ms-850ms	-1.27	-3.59	< .001	-0.99	-2.36	.02
850ms-900ms	-1.32	-3.81	< .001	-1.14	-2.66	< .01
900ms-950ms	-1.47	-4.22	< .001	-1.20	-2.82	< .001
950ms-1000ms	-1.54	-4.58	< .001	-1.28	-3.01	< .001
1000ms-1050ms	-1.64	-4.40	< .001	-1.30	-2.66	< .01
1050ms-1100ms	-1.39	-3.68	< .001	-1.42	-3.17	< .001
1100ms-1150ms	-1.36	-3.48	< .001	-1.59	-3.65	< .001
1150ms-1200ms	-1.28	-3.30	< .001	-1.58	-3.61	< .001
1200ms-1250ms	-1.20	-3.12	< .001	-1.81	-4.09	< .001
1250ms-1300ms	-1.22	-2.91	< .001	-1.70	-3.93	< .001
1300ms-1350ms	-1.42	-3.08	< .001	-1.74	-3.92	< .001
1350ms-1400ms	-0.91	-2.06	.04	-1.25	-3.02	< .001
1400ms-1450ms	-0.95	-237.04	< .001	-1.08	-2.69	< .01
1450ms-1500ms	-0.97	-1.80	.07	-1.07	-2.55	< .01
1500ms-1550ms	-1.70	-2.40	.02	-1.01	-2.01	.04
1550ms-1600ms	-1.57	-2.29	.02	-1.15	-2.00	< .05
1600ms-1650ms	-1.48	-2.02	.04	-0.95	-2.03	.04
1650ms-1700ms	-1.20	-1.73	.08	-1.07	-2.19	.03
1700ms-1750ms	-0.61	-0.95	.34	-1.28	-1.94	.06
1750ms-1800ms	-1.97	-1.98	<.05	-1.05	-1.50	.13
1800ms-1850ms	-1.38	-1.69	.09	-0.93	-1.28	.20
1850ms-1900ms	-0.89	-1.42	.16	-0.34	-0.68	.50
1900ms-1950ms	-0.23	-0.42	.68	0.06	0.12	.90

	Control group			Dyslexic group		
Time-window	***β***	**z**	**p-value**	***β***	**z**	***p*-value**
1950ms-2000ms	0.22	0.40	.69	0.19	0.40	.69
2000ms-2050ms	0.20	0.38	.70	0.10	0.22	.83
2050ms-2100ms	0.69	1.20	.23	0.02	0.03	.98
2100ms-2150ms	1.11	1.66	.10	0.28	0.53	.60

Table 6.5 – Black and white geometric shapes, condition with two target pictures

	Control group			Dyslexic group		
Time-window	***β***	**z**	**p-value**	***β***	**z**	***p*-value**
650ms-700ms	-0.97	-2.75	< .01	-0.74	-1.58	.11
700ms-750ms	-1.18	-3.07	< .001	-0.64	-1.56	.12
750ms-800ms	-1.34	-3.45	< .001	-1.04	-2.33	.02
800ms-850ms	-1.57	-4.28	< .001	-1.20	-2.36	.02
850ms-900ms	-1.76	-4.74	< .001	-0.90	-2.19	.03
900ms-950ms	-2.07	-4.85	< .001	-1.03	-2.49	< .01
950ms-1000ms	-2.18	-5.06	< .001	-1.31	-2.92	< .001
1000ms-1050ms	-1.69	-4.41	< .001	-1.32	-2.96	< .001
1050ms-1100ms	-1.44	-3.94	< .001	-1.14	-2.31	.02
1100ms-1150ms	-1.56	-4.38	< .001	-1.32	-2.27	.02
1150ms-1200ms	-1.63	-4.61	< .001	-1.13	-2.29	.02
1200ms-1250ms	-1.40	-3.96	< .001	-1.48	-376.02	< .001
1250ms-1300ms	-1.20	-3.12	< .001	-1.15	-2.20	.03
1300ms-1350ms	-1.36	-3.26	< .001	-1.39	-2.38	.02
1350ms-1400ms	-1.35	-352.07	< .001	-1.14	-1.80	.07
1400ms-1450ms	-1.57	-374.39	< .001	-1.17	-383.91	< .001
1450ms-1500ms	-1.40	-3.63	< .001	-1.02	-1.83	.07
1500ms-1550ms	-1.33	-3.48	< .001	-0.89	-1.86	.06
1550ms-1600ms	-1.57	-3.57	< .001	-0.86	-1.78	.08
1600ms-1650ms	-1.29	-2.95	< .001	-0.68	-1.59	.11
1650ms-1700ms	-1.06	-2.40	.02	-0.71	-1.57	.12
1700ms-1750ms	-0.95	-2.07	.04	-0.85	-1.74	.08
1750ms-1800ms	-0.61	-1.37	.17	-0.52	-1.15	.25
1800ms-1850ms	-0.52	-1.17	.24	-0.43	-0.99	.32
1850ms-1900ms	-0.54	-1.13	.26	-0.43	-0.93	.35
1900ms-1950ms	-0.66	-1.40	.16	-0.32	-0.73	.47

	Control group			Dyslexic group		
Time-window	***β***	**z**	**p-value**	***β***	**z**	***p*-value**
1950ms-2000ms	-0.44	-1.00	.32	-0.25	-0.57	.57
2000ms-2050ms	-0.19	-49.33	< .001	-0.21	-0.46	.64
2050ms-2100ms	-0.27	-0.60	.55	0.00	0.00	1.00
2100ms-2150ms	-0.41	-0.93	.35	-0.20	-0.44	.66

Table 6.6 – Black and white geometric shapes, condition with three target pictures

	Control group			Dyslexic group		
Time-window	***β***	**z**	**p-value**	***β***	**z**	***p*-value**
650ms-700ms	-0.15	-0.45	.66	-0.22	-0.51	.61
700ms-750ms	-0.53	-1.56	.12	-0.50	-1.11	.27
750ms-800ms	-1.08	-3.01	< .001	-0.85	-1.62	.10
800ms-850ms	-1.44	-3.95	< .001	-0.96	-1.80	.07
850ms-900ms	-1.38	-3.49	< .001	-1.23	-2.45	< .01
900ms-950ms	-0.97	-2.25	.02	-1.25	-2.71	< .01
950ms-1000ms	-1.16	-2.84	< .001	-1.55	-3.38	< .001
1000ms-1050ms	-1.66	-3.72	< .001	-1.67	-3.51	< .001
1050ms-1100ms	-1.83	-4.08	< .001	-1.93	-3.42	< .001
1100ms-1150ms	-2.05	-4.56	< .001	-2.14	-3.12	< .001
1150ms-1200ms	-2.13	-4.47	< .001	-1.90	-2.93	< .001
1200ms-1250ms	-2.05	-4.49	< .001	-2.60	-2.77	< .01
1250ms-1300ms	-2.23	-5.03	< .001	-3.37	-2.60	< .01
1300ms-1350ms	-2.08	-4.66	< .001	-3.16	-2.59	< .01
1350ms-1400ms	-1.58	-3.97	< .001	-2.29	-2.94	< .001
1400ms-1450ms	-1.42	-3.59	< .001	-2.35	-3.01	< .001
1450ms-1500ms	-1.41	-346.49	< .001	-1.95	-2.43	.02
1500ms-1550ms	-1.47	-3.48	< .001	-1.72	-2.17	.03
1550ms-1600ms	-1.60	-3.75	< .001	-1.33	-1.88	.06
1600ms-1650ms	-1.67	-3.83	< .001	-0.75	-1.61	.11
1650ms-1700ms	-1.67	-3.60	< .001	-0.55	-1.21	.23
1700ms-1750ms	-1.67	-3.59	< .001	-0.59	-1.27	.20
1750ms-1800ms	-1.64	-3.51	< .001	-0.94	-1.91	.06
1800ms-1850ms	-2.15	-4.09	< .001	-1.12	-2.11	.04
1850ms-1900ms	-2.22	-647.94	< .001	-1.60	-2.89	< .001
1900ms-1950ms	-1.85	-3.51	< .001	-1.65	-2.98	< .001

	Control group			Dyslexic group		
Time-window	***β***	**z**	**p-value**	***β***	**z**	***p*-value**
1950ms-2000ms	-1.56	-3.36	< .001	-1.51	-2.92	< .001
2000ms-2050ms	-1.41	-2.97	< .001	-1.41	-2.71	< .01
2050ms-2100ms	-1.22	-2.41	.02	-1.44	-2.60	< .01
2100ms-2150ms	-1.35	-2.48	< .01	-1.56	-2.59	< .01

Table 6.7 – Coloured geometric shapes, condition with one target picture

	Control group			Dyslexic group		
Time-window	***β***	**z**	**p-value**	***β***	**z**	***p*-value**
650ms-700ms	-0.47	-1.40	.16	-0.51	-0.80	.43
700ms-750ms	-1.25	-3.44	< .001	-1.00	-402.23	< .001
750ms-800ms	-1.40	-3.76	< .001	-1.04	-1.60	.11
800ms-850ms	-1.56	-4.12	< .001	-1.14	-1.71	.09
850ms-900ms	-1.94	-4.91	< .001	-1.28	-2.23	.03
900ms-950ms	-2.04	-4.55	< .001	-1.18	-1.98	< .05
950ms-1000ms	-1.70	-4.07	< .001	-0.94	-1.92	.06
1000ms-1050ms	-1.57	-3.54	< .001	-1.04	-1.67	.09
1050ms-1100ms	-1.38	-2.32	.02	-1.10	-1.67	.09
1100ms-1150ms	-1.96	-2.51	< .01	-1.74	-2.24	.03
1150ms-1200ms	-1.91	-2.42	.02	-1.83	-2.45	< .01
1200ms-1250ms	-1.37	-1.66	.10	-0.92	-1.56	.12
1250ms-1300ms	-0.72	-0.85	.39	-0.81	-1.41	.16
1300ms-1350ms	-0.93	-202.35	< .001	-0.23	-0.39	.70
1350ms-1400ms	-0.91	-1.03	.30	0.51	0.86	.39
1400ms-1450ms	-0.61	-0.65	.51	0.40	0.68	.50
1450ms-1500ms	-0.62	-0.66	.51	0.40	0.68	.50
1500ms-1550ms	-0.66	-0.53	.60	0.37	0.65	.52
1550ms-1600ms	0.07	0.05	.96	-0.19	-0.31	.76
1600ms-1650ms	-0.32	-0.34	.73	-0.21	-0.35	.73
1650ms-1700ms	0.33	0.47	.64	0.01	0.02	.99
1700ms-1750ms	0.78	1.16	.25	-0.22	-0.34	.73
1750ms-1800ms	1.06	1.48	.14	-0.13	-0.17	.86
1800ms-1850ms	0.50	0.89	.37	-0.31	-0.40	.69
1850ms-1900ms	0.52	0.84	.40	-0.39	-0.61	.55
1900ms-1950ms	0.03	0.05	.96	-0.51	-0.88	.38

	Control group			Dyslexic group		
Time-window	***β***	**z**	**p-value**	***β***	**z**	***p*-value**
1950ms-2000ms	0.03	0.05	.96	-0.62	-1.03	.30
2000ms-2050ms	0.66	0.87	.39	-0.38	-0.62	.53
2050ms-2100ms	9.37	2.03	.04	-0.21	-0.34	.73
2100ms-2150ms	-0.53	-356.98	< .001	-0.13	-0.20	.84

Table 6.8 – Coloured geometric shapes, condition with two target pictures

	Control group			Dyslexic group		
Time-window	***β***	**z**	**p-value**	***β***	**z**	***p*-value**
650ms-700ms	-1.22	-3.31	< .001	-0.27	-0.69	.49
700ms-750ms	-1.23	-3.62	< .001	-0.48	-1.19	.23
750ms-800ms	-1.60	-4.55	< .001	-0.97	-2.35	.02
800ms-850ms	-2.01	-5.09	< .001	-1.33	-3.14	< .001
850ms-900ms	-2.36	-5.99	< .001	-1.39	-3.29	< .001
900ms-950ms	-2.86	-6.10	< .001	-1.32	-3.07	< .001
950ms-1000ms	-3.03	-6.24	< .001	-1.41	-3.24	< .001
1000ms-1050ms	-3.07	-5.60	< .001	-1.26	-2.95	< .001
1050ms-1100ms	-2.63	-4.98	< .001	-1.65	-3.31	< .001
1100ms-1150ms	-2.46	-4.78	< .001	-1.42	-2.83	< .001
1150ms-1200ms	-2.01	-4.50	< .001	-1.00	-2.14	.03
1200ms-1250ms	-1.82	-4.20	< .001	-0.95	-2.00	< .05
1250ms-1300ms	-1.78	-3.89	< .001	-0.90	-1.83	.07
1300ms-1350ms	-1.50	-3.24	< .001	-1.36	-2.48	< .01
1350ms-1400ms	-1.39	-2.96	< .001	-1.15	-2.24	.03
1400ms-1450ms	-1.54	-3.05	< .001	-0.85	-1.79	.07
1450ms-1500ms	-1.91	-3.61	< .001	-0.73	-1.61	.11
1500ms-1550ms	-1.58	-3.16	< .001	-0.74	-1.64	.10
1550ms-1600ms	-1.64	-2.90	< .001	-0.54	-1.11	.27
1600ms-1650ms	-0.90	-1.81	.07	-0.45	-0.93	.35
1650ms-1700ms	-0.72	-1.62	.11	-0.52	-1.04	.30
1700ms-1750ms	-0.69	-1.40	.16	-0.52	-1.02	.31
1750ms-1800ms	-0.57	-1.20	.23	-0.78	-1.31	.19
1800ms-1850ms	-0.70	-1.44	.15	-0.13	-0.25	.80
1850ms-1900ms	-0.42	-0.85	.40	-0.56	-1.04	.30
1900ms-1950ms	-0.47	-0.90	.37	-0.41	-0.79	.43

	Control group			Dyslexic group		
Time-window	***β***	**z**	**p-value**	***β***	**z**	***p*-value**
1950ms-2000ms	-0.37	-0.63	.53	-0.59	-1.11	.27
2000ms-2050ms	-0.23	-0.42	.68	-0.56	-1.05	.29
2050ms-2100ms	-0.32	-0.56	.58	-0.41	-0.72	.47
2100ms-2150ms	-0.18	-0.31	.76	-0.13	-0.23	.82

Table 6.9 – Coloured geometric shapes, condition with three target pictures

	Control group			Dyslexic group		
Time-window	***β***	**z**	**p-value**	***β***	**z**	***p*-value**
650ms-700ms	-0.70	-2.15	.03	-0.88	-1.65	.10
700ms-750ms	-0.99	-2.96	< .001	-1.18	-2.31	.02
750ms-800ms	-1.22	-3.61	< .001	-1.70	-2.95	< .001
800ms-850ms	-1.47	-4.25	< .001	-2.03	-4.01	< .001
850ms-900ms	-1.74	-4.92	< .001	-2.35	-4.30	< .001
900ms-950ms	-1.90	-5.20	< .001	-2.63	-4.22	< .001
950ms-1000ms	-2.04	-5.13	< .001	-2.45	-4.50	< .001
1000ms-1050ms	-2.00	-425.67	< .001	-2.73	-4.12	< .001
1050ms-1100ms	-2.19	-4.82	< .001	-3.54	-3.71	< .001
1100ms-1150ms	-2.35	-4.70	< .001	-2.78	-3.46	< .001
1150ms-1200ms	-2.18	-4.23	< .001	-2.83	-3.63	< .001
1200ms-1250ms	-2.00	-4.03	< .001	-2.06	-3.47	< .001
1250ms-1300ms	-1.86	-3.72	< .001	-2.11	-3.55	< .001
1300ms-1350ms	-1.96	-3.64	< .001	-1.99	-3.36	< .001
1350ms-1400ms	-1.80	-3.63	< .001	-1.52	-3.02	< .001
1400ms-1450ms	-1.96	-3.65	< .001	-1.83	-3.22	< .001
1450ms-1500ms	-2.08	-3.69	< .001	-1.75	-3.04	< .001
1500ms-1550ms	-1.61	-2.52	< .01	-1.46	-2.68	< .01
1550ms-1600ms	-1.60	-2.53	< .01	-1.25	-1.97	< .05
1600ms-1650ms	-1.44	-2.50	< .01	-1.20	-1.96	.06
1650ms-1700ms	-1.07	-1.82	.07	-1.40	-2.34	.02
1700ms-1750ms	-0.98	-1.70	.09	-0.84	-1.62	.10
1750ms-1800ms	-1.13	-2.14	.03	-0.78	-1.57	.12
1800ms-1850ms	-1.01	-1.89	.06	-0.79	-1.54	.12
1850ms-1900ms	-1.29	-2.28	.02	-0.51	-0.95	.34
1900ms-1950ms	-1.34	-2.41	.02	-0.47	-0.93	.35

	Control group			Dyslexic group		
Time-window	***β***	**z**	**p-value**	***β***	**z**	***p*-value**
1950ms-2000ms	-1.24	-2.22	.03	-0.49	-0.97	.33
2000ms-2050ms	-1.09	-1.95	.06	-0.49	-1.02	.31
2050ms-2100ms	-1.33	-2.14	.03	-0.95	-1.77	.08
2100ms-2150ms	-0.88	-1.46	.14	-1.10	-1.93	.06

References

Acquaviva, P. (1997). *The logical form of negation: A study of operator-variable structures in syntax.* Garland Pub.

Alemanno, F., Houdayer, E., Cursi, M., Velikova, S., Tettamanti, M., Comi, G., & Leocani, L. (2012). Action-related semantic content and negation polarity modulate motor areas during sentence reading: An event-related desynchronization study. *Brain Research, 1484*, 39-49.

Allopenna, P. D., Magnuson, J. S., & Tanenhaus, M. K. (1998). Tracking the time course of spoken word recognition using eye movements: Evidence for continuous mapping models. *Journal of Memory and Language, 38*, 419-439.

Alloway, T. P., & Alloway, R. G. (2013). Working memory across the lifespan: A cross-sectional approach. *Journal of Cognitive Psychology, 25(1)*, 84-93.

Altmann, G. T., & Kamide, Y. (1999). Incremental interpretation at verbs: Restricting the domain of subsequent reference. *Cognition, 73*, 247−264.

Altmann, G. T., & Kamide, Y. (2007). The real-time mediation of visual attention by language and world knowledge: Linking anticipatory (and other) eye movements to linguistic processing. *Journal of Memory and Language, 57*, 502−518.

Altmann, G. T., & Kamide, Y. (2009). Discourse-mediation of the mapping between language and the visual world: Eye-movements and mental representation. *Cognition, 111*, 55-71.

Andersson, U. (2010). The contribution of working memory capacity to foreign language comprehension in children. *Memory, 18(4)*, 458-472.

Antinucci, V., & Volterra, F. (1979). Negation in Child Language: A Pragmatic Study. *Developmental Pragmatics*, 281-303.

Aparicio, H., Xiang, M., & Kennedy, C. (2015). Processing gradable adjectives in context: A visual world study. *Proceedings of SALT 25* (pp. 413-432). LSA and CLC Publications.

Aravena, P., Delevoye-Turrell, Y., Deprez, V., Cheylus, A., Paulignan, Y., Frak, V., & Nazir, T. (2012). Grip force reveals the context sensitivity of language-induced motor activity during "action words" processing: Evidence from sentential negation. *PloS One, 7(12)*.

Arroyo, F. V. (1982). Negatives in context. *Journal of Verbal Learning and Verbal Behavior, 21*, 118-126.

Atkinson, R. C., & Shiffrin, R. M. (1968). *Human memory: A proposed system and its control processes.* (Vol. The psychology of learning and motivation). (K. W. Spence, & J. T. Spence, Eds.) New York: Academic Press.

Avrutin, S., & Wexler, K. (1992). Development of principle B in Russian: Coindexation at LF and coreference. *Language Acquisition, 2*, 259-306.

Baddeley, A. D. (1986). *Working memory.* Oxford: Oxfor University Press.

Baddeley, A. D. (2000). The episodic buffer: a new component of working memory? *Trends in Cognitive Science*, *4*, 417-423.

Baddeley, A. D. (2002). The psychology of memory. In A. D. Baddeley, B. A. Wilson, & M. Kopelma, *Handbook of Memory Disorders* (2nd ed.). Hove: Psychology Press.

Baddeley, A. D. (2003). Working memory and language: An overview. *Journal of Communication Disorders, 36,* 189-208.

Baddeley, A. D., & Hitch, G. J. (1974). *Working memory* (Vol. The Psychology of Learning and Motivation). (G. A. Bower, Ed.) New York: Academic Press.

Baker, C. L. (1970). Double negatives. *Linguistic Inquiry, 1(2),* 169-186.

Bar-Shalom, E., Crain, S., & Shankweiler, D. (1993). Comparison of comprehension and production in good and poor readers. *Applied Psycholinguistics, 14*, 197-227.

Bartoli, E., Tettamanti, M., Farronato, P., Caporizzo, A., Moro, A., & Gatti, R. (2013). The disembodiment effect of negation: Negating action-related sentences attenuates their interference on congruent upper limb movements. *Journal of Neurophysiology, 109(7)*, 1782–1792.

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software, 67,* 1-48.

Belletti, A. (1990). *Generalized verb movement: Aspects of verb syntax.* Rosenberg & Sellier.

Bellugi, U. (1967). *The acquisition of the system of negation in children's speech.* Harvard Graduate School of Education.

Beltrán, D., Orenes, I., & Santamaría, C. (2008). Context effects on the spontaneous production of negation. *Intercultural Pragmatics,* 5-14.

Benfatto, M. N., Seimyr, G. O., Ygge, J., Pansell, T., Rydberg, A., & Jacobson, C. (2016). Screening for dyslexia using eye tracking during reading. *Plos One, 11(12).*

Benincà, P. (2006). A detailed map of the left periphery of medieval Romance. In *Crosslinguistic research in syntax and semantics: Negation, tense and clausal architecture* (pp. 53-86).

Blachman, B. A. (1994). Early literacy acquisition – the role of phonological awareness. In G. Wallach, & K. Butler, *Language learning disabilities in schoolage children and adolescents: Some underlying principles and applications.* Columbus, OH: Merrill.

Blachman, B. A. (1997). *Foundations of reading acquisition and dyslexia.* Mahwah, NJ: Erlbaum.

Blachman, B. A. (2000). Phonological awareness. In M. L. Kamil, P. B. Mosenthal, P. D. Pearson, & R. Barr, *Handbook of reading research.* Mahwah, NJ: Erlbaum.

Bloom, L. (1970). *Language Development: Form and Function in Emerging Grammars.* Cambridge: MIT Press.

Bourassa, D., & Treiman, R. (2003). Spelling in Children With Dyslexia: Analyses From the Treiman–Bourassa Early Spelling Test. *Scientific Studies of Reading, 4*, 309-333.

Bowers, P. G., & Wolf, M. (1993). Theoretical links among naming speed, precise timing mechanisms and orthographic skill in dyslexia. *Reading and Writing: An Interdisciplinary Journal, 5(1)*, 69-85.

Bowey, J. A. (1994). Phonological sensitivity in novice readers and non-readers. *Journal of Experimental Child Psychology, 58*, 134-159.

Bradley, L., & Bryant, P. (1983). Categorizing sounds and learning to read—a causal connection. *Nature, 301*, 419-421.

Brady, S. A., Shankweiler, D., & Mann, V. (1983). Speech perception and memory coding in relation to reading ability. *Journal of Experimental Child Psychology, 35*, 346-367.

Breithbarth, A. (2011). Modality and negation in the history of Low German. *Zeitschrift für Sprachwissenschaft, 30*, 131-167.

Brosnan, M., Demetre, J., Hamill, S., Robson, K., Shepherd, H., & Cody, G. (2002). Executive functioning in adults and children with developmental dyslexia. *Neuropsychologia, 40(12)*, 2144-2155.

Bruck, M. (1992). Persistence of dyslexics' phonological awareness deficits. *Developmental Psychology, 28(5)*, 874-886.

Burton-Roberts, N. (1989). On Horn's dilemma: Presupposition and negation. *Journal of Linguistics, 25(1)*, 95-125.

Byrne, B. (1981). Deficient syntactic control in poor readers: Is a weak phonetic memory code responsible? *Applied Psycholinguistics, 2*, 201-212.

Cameron-Faulkner, T., Lieven, E., & Theakston, A. (2007). What part of no do children not understand? A usage-based account of multiword negation. *Journal of Child Language, 34(2)*.

Canseco-Gonzalez, E., Brehm, L., Brick, C., Brown-Schmidt, S., Fischer, K., & Wagner, K. (2010). Carpet or Cárcel: Effects of age of acquisition and language proficiency on bilingual lexical access. *Language and Cognitive Processes, 25*, 669-705.

Cardinaletti, A., & Volpato, F. (2015). On the comprehension and production of passive and relative clauses by dyslexic University students. In E. Di Domenico, C. Hamann, & S. Matteini, *Structures, Strategies and Beyond. Studies in Honour of Adriana Belletti* (pp. 279-301). Amsterdam/Philadelphia: Benjamins.

Carpenter, P., & Just, M. (1975). Sentence comprehension: A psycholinguistic processing model of verification. *Psychological Review, 82(1)*, 45–73.

Carpenter, P., Just, M., Keller, T., Eddy, W. F., & Thulborn, K. R. (1999). Time course of fMRI-activation in language and spatial networks during sentence comprehension. *NeuroImage, 10(2)*, 216-224.

Carroll, J. M., & Snowling, M. J. (2004). Language and phonological skills in children at high risk of reading difficulties. *Journal of child psychology and psychiatry, 45(3)*, 631-640.

Chambers, C. G., Tanenhaus, M. K., & Magnuson, J. S. (2004). Action-based affordances and syntactic ambiguity resolution. *Journal of Experimental Psychology: Learning, Memory & Cognition, 30*, 687−696.

Chien, Y. /. (1990). Children’s Knowledge of Locality Conditions in Binding as Evidence for the Modularity of Syntax and Pragmatics. *Language Acquisition, 1*, 225-295.

Choi, S. (1988). The semantic development of negation: a cross-linguistic longitudinal study. *Journal of Child Language, 15*, 517-531.

Chomsky, N. (1957). *Syntactic structures.* Berlin: Mouton & Co.

Chomsky, N. (1965). *Aspects of the theory of syntax.* Cambridge, MA: MIT Press.

Chomsky, N. (1969). *The acquisition of syntax in children from 5 to 10.* Cambridge: MA: MIT Press.

Chomsky, N. (1980). On binding. *Linguistic Inquiry, 11*, 1-46.

Chomsky, N. (1981). *Lectures on Government and Binding.* Dordrecht: Foris.

Cirillo, R. J. (2009). *The syntax of floating quantifiers: stranding revisited.* Amsterdam: LOT.

Clahsen, H. (1988). Parameterized grammatical theory and language acquisition. In *Linguistic theory in second language acquisition* (pp. 47-75). Dordrecht: Springer.

Clark, H., & Chase, W. (1972). On the process of comparing sentences against pictures. *Cognitive Psychology, 3,* 472–517.

Colombo, L., Fudio, S., & Mosna, G. (2009). Phonological and working memory mechanisms involved in written spelling. *European Journal of Cognitive Psychology, 21(6),* 837-861.

Coltheart, M. (1985). *Cognitive neuropsychology and the study of reading.* (M. Posner, & O. S. Marin, Eds.) Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual route cascaded model of visual word recognition and reading aloud. *Psychological Review 108*, 204-256.

Cooper, R. M. (1974). The control of eye fixation by the meaning of spoken language: A new methodology for the real-time investigation of speech perception, memory, and language processing. *Cognitive Psychology, 6*, 84-107.

Cromer, R. F. (1970). Children are nice to understand: surface structures clues for the recovery of a deep structure. *British Journal of Psychology, 61*, 397-408.

Dahan, D., & Tanenhaus, M. K. (2005). Looking at the rope when looking for the snake: Conceptually mediated eye movements during spoken-word recognition. *Psychonomic Bulletin & Review, 12,* 453-459.

Dahan, D., Magnuson, J., & Tanenhaus, M. K. (2001). Time course of frequency effects in spoken-word recognition: Evidence from eye movements. *Cognitive Psychology, 42*, 317-367.

Dahl, Ö. (1979). Typology of sentence negation. *Linguistics, 17(1-2),* 79-106.

Dale, R., & Duran, N. D. (2011). The cognitive dynamics of negated sentence verification. *Cognitive Science, 35(5)*, 983–996.

De Jong, P., & Leij, A. v. (1999). Specific contributions of phonological abilities to early reading acquisition: results from a Dutch latent variable longitudinal study. *Journal of Educational Psychology, 91*, 450-475.

de Swart, H. E., & Sag, I. A. (2002). Negative concord in Framce. *Lingusitics and Philosophy, 25*, 373-417.

De Vincenzi, M. (1991). *Syntactic Parsing Strategies in Italian: The Minimal Chain Principle, vol. 12.* Dordrecht/Boston/London: Kluwer Academic Publishers.

Démonet, J. F., Taylor, M. J., & Chaix, Y. (2004). Developmental dyslexia. *Lancet, 363,* 1451-60.

Denckla, M. B. (1972). Color-naming defects in dyslexic boys. *Cortex, 8,* 164-176.

Denckla, M. B., & Rudel, R. G. (1976). Naming of objects by dyslexic and other learning-disabled children. *Brain and Language, 3,* 1-15.

Deprez, V., & Pierce, A. (1993). Negation and functional projections in early grammar. *Linguistic Inquiry, 24,* 25-67.

Desroches, A. S., Joanisse, M. F., & Robertson, E. K. (2006). Specific phonological impairments in dyslexia revealed by eyetracking. *Cognition, 100(3),* B32-B42.

Deutsch, R., Gawronski, B., & Strack, F. (2006). At the boundaries of automaticity: Negation as reflective operation. *Journal of Personality and Social Psychology, 91(3),* 385-405.

Dijk, T. v., & Kintsch, W. (1983). *Strategies of discourse comprehension.* New York: New York Academy Press.

Dimroth, C. (2011). The acquisition of negation. In L. R. Horn, *The expression of cognitive categories vol. 4: The expression of negation* (pp. 39-71). New Haven, US: De Gruyter Mouton.

Drodz, K. F. (1995). Child English pre-sentential negation as metalinguistic exclamatory sentence negation. *Journal of Child Language, 22*, 538-610.

Duchowski, A. (2003). *Eye tracking methodology: Theory and practice.* London: Springer-Verlag.

Dunabeitia, J. A., Aviles, A., Afonso, O., Scheepers, C., & Carreiras, M. (2009). Qualitative differences in the representation of abstract versus concrete words: Evidence from the visual-world paradigm. *Cognition, 110,* 284-292.

Eiferman, R. R. (1961). Negation, a linguistic variable. *Acta Psychologica, 18,* 258-273.

Elbro, C. (1997). Early linguistic abilities and reading development: A review and a hypothesis about underlying differences in distinctiveness of phonological representations of lexical items. *Reading and Writing, 8,* 453-485.

Evans, J., & Over, D. E. (2004). *If.* London: Oxford University Press.

Everatt, J., Turner, J., & Miles, T. R. (1997). The incidence of Stroop Interference in dyslexia. *Dyslexia, 3*, 222-228.

Facoetti, A., Lorusso, M. L., Paganoni, P., Cattaneo, C., Galli, R., & Umiltà, C. (2003). Auditory and visual automatic attention deficits in developmental dyslexia. *Cognitive Brain Research, 16(2)*, 185-191.

Facoetti, A., Paganoni, P., & Turatto, M. (2000). Visual-spatial attention in developmental dyslexia. *Cortex, 36(1)*, 109-123.

Fawcett, A. J., & Nicolson, R. I. (1994). Naming speed in children with dyslexia. *Journal of Learning Disabilities*, *27*, 641-646.

Felix, S. (1987). *Cognition and language growth.* Michigan: Foris Publications.

Felton, R. H., Naylor, C. E., & Wood, F. B. (1990). Neuropsychological profile of adult dyslexics. . *Brain and Language*, *39*, 485–497.

Ferguson, H. J., Sanford, A. J., & Leuthold, H. (2008). Eye-movements and ERPs reveal the time course of processing negation and remitting counterfactual worlds. *Brain Research*, *123(6)*, 113–25.

Fiorin, G. (2010). *Meaning and dyslexia: a study on pronouns, aspect and quantification. Doctoral dissertation.* Utrecht Institute for Linguistics OTS: LOT Series.

Fischler, I., Bloom, P., & Childers, D. (1983). Brain potentials related to stages of sentence verification. *Psychophysiology, 20(4)*, 400-409.

Flesch, R. F. (1951). *How to test readability.* New York: Harper.

Fodor, J. (1983). *The modularity of mind.* Mass: MIT Press Cambridge.

Foroni, F., & Semin, G. R. (2013). Comprehension of action negation involves inhibitory simulation. *Frontiers in Human Neuroscience, 7*, 1-7.

Forster, K. I. (1970). Visual perception of rapidly presented word sequences of varying complexity. *Perception & Psychophysics, 8* , 215-221.

Frazier, L. (1979). *On comprehending sentences: Syntactic parsing strategies. Ph.D. Dissertation.* University of Connecticut: Indiana University Linguistics Club.

Frazier, L. (1987). Sentence processing: A tutorial review. In M. Coltheart, *Attention and performance XII: The psychology of reading* (pp. 559-586). Hillsdale, NJ: Lawrence Erlbaum Associates.

Frege, G. (1884). *Die Grundlagen der Arithmetik: eine logisch mathematische Untersuchung über den Begriff der Zahl.* . Koebner.

Frege, G. (1892). Über Sinn und Bedeutung. *Zeitschrift für Philosophie und philosophische Kritik, 100*, 25-50.

Frege, G. (1952). *Translations from the Philosophical Writings of Gottlob Frege.* (P. Geach, & M. Black, Eds.)

Friend, A., DeFries, J. C., & Olson, R. K. (2008). Parental education moderates genetic influences on reading disability. *Psychological Science*, 1124-1130.

Frost, R. (1998). Towards a strong phonological theory of visual word recognition: True issues and false trails. *Psychological Bulletin, 123*, 71-99.

Gadsby, N., Arnott, W. L., & Copland, D. A. (2008). An investigation of working memory influences on lexical ambiguity resolution. *Neuropsychology, 22(2),* 209-216.

Gagliano, A., Germanò, E., Calabrese, T., Magazù, A., Grosso, R., Siracusano, R. M., & Cedro, C. (2007). La comorbidità nella dislessia: studio di un campione di soggetti in età evolutiva con disturbo di lettura. *Dislessia, 4*, 21-39.

Galaburda, A. M., LoTurco, J., Ramus, F., Fitch, R. H., & Rosen, G. D. (2006). From genes to behavior in developmental dyslexia. *Nature Neuroscience, 9(10)*, 1213–1217.

Gathercole, S. E., & Baddeley, A. D. (1990). Phonological memory deficits in language disordered children: Is there a causal connection? *Journal of Memory and Language, 29*, 336-360.

Gathercole, S., & Baddeley, A. (2014). *Working memory and language processing.* New York: Psychology Press.

Gayan, J., & Olson, R. K. (1999). Reading disability: Evidence for a genetic etiology. *European Child & Adolescent Psychiatry, 8*, 52-55.

Ghani, K. A., & Gathercole, S. E. (2013). Working memory and study skills: a comparison between dyslexic and non-dyslexic adult learners. *Procedia - Social and Behavioral Sciences 97* , 271-277.

Ghidoni, E., & Angelini, D. (2007). La diagnosi di dislessia evolutiva in Italia: situazione e prospettive dall'infanzia all'età adulta. *Lo Spallanzani, 21(2),* 87-94.

Ghio, M., & Tettamanti, M. (2010). Semantic domain-specific functional integration for action-related vs. abstract concepts. *Brain and Language, 112(3)*, 223–232.

Giannakidou, A. (1997). *The landscape of Polarity Items.* Rijksuniversiteit Groningen.

Giannakidou, A. (1998). *Polarity sensitivity as (non) veridical dependency* (Vol. 23). Amsterdam: John Benjamins Publishing Company.

Giannakidou, A. (2000). Negative... Concord? *Natural Language and Linguistic Theory, 18*, 475-523.

Gibson, E. (1991). *computational Theory of Human Linguistic Processing: Memory Limitations and Processing Breakdown. Doctoral Dissertation.* Pittsburgh, PA: Carnegie Mellon University.

Gibson, E. (1998). Linguistic complexity: Locality of syntactic dependencies. *Cognition, 68*, 1-76.

Ginzburg, J. (2012). *The interactive stance.* Stanford: CSLI Publications.

Giora, R. (2006). Anything negatives can do affirmatives can do just as well, except for some metaphors. *Journal of Pragmatics, 38(7)*, 981–1014.

Giora, R., Aschkenazi, K., & Fein, O. (2004). Suppression is not obligatory but functional: on negative metaphors. *Euroconference on Computational and Neuropsychological Approaches to Metaphor and Metonymy.* Granada.

Giora, R., Balan, N., Fein, O., & Alkabets, I. (2005). Negation as positivity in disguise. In H. L. Colston, & A. Katz, *Figurative language comprehension: Social and cultural influence* (pp. 233–258). NJ: Erlbaum, Hillsdale.

Giora, R., Fein, O., Aschkenazi, K., & Alkabets-Zlozover. (2007). Negation in context: A functional approach to suppression. *Discourse Processes, 43(2)*, 153-172.

Givón, T. (1978). Negation in language: pragmatics, function, ontology. In C. P., *Syntax and Semantics 9: Pragmatics.* New York: Academic Press.

Glenberg, A. M., Robertson, D. A., Jennifer, L. J., & Johnson-Glenberg, M. C. (1999). Not propositions. *Cognitive Systems Research, 1(1)*, 19-33.

Gough, P. (1966). The verification of sentences: The effects of delay of evidence and sentence length . *Journal of Verbal Learning and Verbal Behavior, 5(5)*, 492–496.

Greenberg, J. (1966). *universals, with special reference to feature hierarchies.* Mouton: The Hague.

Grice, H. P. (1975). *Logic and conversation* (Vol. Syntax and semantics 3: Speech acts). (P. Cole, & J. Morgan, Eds.) New York: Academic Press.

Griffin, Z., & Bock, K. (2000). Whay eyes say about speaking. *Psychological Science*, 274-279.

Griffiths, C. C. (2007). Pragmatic abilities in adults with and without dyslexia: a pilot study. *Dyslexia, 13(4)*, 276-296.

Grodner, D., & Gibson, E. (2005). Consequences of the Serial Nature of Linguistic Input for Sentenial Complexity. *Cognitive Science, 29(2),* 261-290.

Guasti, M. T., Branchini, C., Vernice, M., Barbieri, L., & Arosio, F. (2015). Language disorders in children with Developmental Dyslexia. In S. Stavrakaki, *Specific Language Impairment. Current trends in research* (pp. 35-55). Amsterdam: John Benjamins Publishing Company.

Haegeman, L. (1995). *The syntax of negation* (Vol. Cambridge Studies in Linguistics 75). Cambridge: Cambridge University Press.

Haegeman, L., & Zanuttini, R. (1991). Negative Heads and the Neg-Criterion. *The Linguistic Review, 8,* 233-251.

Haegeman, L., & Zanuttini, R. (1996). Negative concord in west flemish. *Parameters and functional heads. Essays in comparative syntax, 3*, 117-197.

Hakes, D. T. (1972). Effects of reducing complement constructions on sentence comprehension. *Journal of Verbal Learning and Verbal Behavior, 11*, 278-286.

Hari, R., Valta, M., & Uutela, K. (1999). Prolonged attentional dwell time in dyslexics adults. *Neuroscience Letters, 271*, 202-204.

Hasson, U., & Glucksberg, S. (2006). Does understanding negation entail affirmation? An examination of negated metaphors. *Journal of Pragmatics, 38(7)*, 1015–1032.

Helland, T., & Asbjornsen, A. (2004). Digit span in dyslexia: Variations according to language comprehension and mathematics skills. *Journal of Clinical and Experimental Neuropsychology, 26*, 31-42.

Herburger, E. (2001). The negative concord puzzle revisited. *Natural language semantics, 9(3),* 289-333.

Hollebrandse, B., & Van Hout, A. (2001). On the acquisition of the aspects in Italian. In J. Y. Kim, & A. Werle (Ed.), *The Proceedings of SULA: the Semantics of Underrepresented Languages in the Americas.* Amherst: GLSA.

Holmes, V. M., & Forster, K. I. (1972). Perceptual complexity and underlying sentence structure. *Journal of Verbal Learning and Verbal Behavior, 11,* 148-156.

Horn, L. R. (1984). *Toward a new taxonomy for pragmatic inference: Q-based and R-based implicature* (Vols. Meaning, Form, and Use in Context: Linguistic Applications). (D. Schiffrin, Ed.) Washington D.C.: Georgetown University Press.

Horn, L. R. (1985). Metalinguistic negation and pragmatic ambiguity. *Language, 61(1)*, 121-174.

Horn, L. R. (1989). *A natural history of negation.* Chicago: University of Chicago Press.

Hu, S., Vender, M., Fiorin, G., & Delfitto, D. (2018). Difficulties in Comprehending Affirmative and Negative Sentences: Evidence From Chinese Children With Reading Difficulties. *Journal of Learning Disabilities, 51(2)*, 181-193.

Huettig, F., & Altmann, G. T. (2004). The online processing of ambiguous and unambiguous words in context: Evidence from head-mounted eye-tracking. In M. Carreiras, & C. Clifton, *The on-line study of sentence comprehension: Eyetracking, ERP and beyond* (pp. 187-207). New York, NY: Psychology Press.

Huettig, F., & Altmann, G. T. (2005). Word meaning and the control of eye fixation: Semantic competitor effects and the visual world paradigm. *Cognition, 96*, B23-B32.

Huettig, F., & Altmann, G. T. (2007). Visual-shape competition during language-mediated attention is based on lexical input and not modulated by contextual appropriateness. *Visual Cognition, 15*, 985-1018.

Huettig, F., & Altmann, G. T. (2011). Looking at anything that is green when hearing 'frog' – How object surface color and stored object color knowledge influence language-mediated overt attention. *Quarterly Journal of Experimental Psychology, 64*, 122-145.

Huettig, F., & Brouwer, S. (2015). Delayed anticipatory spoken language processing in adults with dyslexia - evidence from eye-tracking. *Dyslexia, 21(2)*, 97-122.

Huettig, F., & McQueen, J. M. (2007). The tug of war between phonological, semantic, and shape information in language-mediated visual search. *Journal of Memory and Language, 54*, 460-482.

Huettig, F., Rommers, J., & Meyer, A. S. (2011). Using the visual world paradigm to study language processing: A review and critical evaluation. *Acta Psychologica, 137*, 151-171.

Hulme, C., & Roodenrys, S. (1995). Practitioner review: verbal working memory development and its disorders. *Journal of Child Psychology and Psychiatry, 36*, 373-398.

Hummer, P. (1993). On the origins of denial negation. *Journal of Child Language, 20*, 607-618.

Humphreys, G. W., & Evett, L. J. (1985). Are there independent lexical and nonlexical routes in word processing? An evaluation of the dual-route theory of reading. *Behavioural and Brain Sciences 8(4)*, 689-740.

Hutzler, F., & Wimmer, H. (2004). Eye movements of dyslexic children when reading in a regular orthography. *Brain and Language, 89(1),* 235-242.

Jackendoff, R. S. (1969). An Interpretive Theory of Negation. *Foundations of Language, 5*, 218-241.

Jackendoff, R. S. (1972). *Semantic Interpretation in Generative Grammar.* Cambridge, MA: MIT Press.

Jaeger, T. F. (2008). Categorical Data Analysis: Away from ANOVAs (transformation or not) and towards Logit Mixed Models. *Journal of Memory and Language, 59*, 434-446.

Jarrett, C. (2009). Working memory predicts learning outcomes. *Psychologist, 22(10)*, 827.

Jeffries, S., & Everatt, J. E. (2004). Working memory: Its role in dyslexia and other specific learning difficulties. *Dyslexia, 10,* 196-214.

Jiménez, J. E., Garcìa, E., Estévez, A., Dìaz, A., R., G., Hernandez-Valle, I., . . . Hernandéz, S. (2004). An evaluation of syntactic-semantic processing in developmental dyslexia. *Electronic Journal of Research in Educational Psychology, 2*, 127-142.

Joanisse, M. F., Manis, F. R., Keating, P., & Seidenberg, M. S. (2000). Language Deficits in Dyslexic Children: Speech Perception, Phonology and Morphology. *Journal of Experimental Child Psychology, 77*, 30-60.

Johnson-Laird, P. (1983). *Mental models: Towards a cognitive science of language, inference, and consciousness.* Cambridge: Cambridge University Press.

Johnson-Laird, P. N. (2001). Mental models and deduction. *TRENDS in Cognitive Sciences, 5(10)*, 434-442.

Johnston, R. S., Anderson, M., & Holligan, C. (1996). Knowledge of the alphabet and explicit awareness of phonemes in prereaders: the nature of the relationship. *Reading and Writing, 8,* 217-234.

Jordens, P. (2002). Finiteness in early child Dutch. *Linguistics, 40*, 687-765.

Jordens, P., & Dimroth, C. (2006). Finiteness in children and adults learning Dutch. In *The acquisition of verbs and their grammar: The effect of particular languages* (pp. 173-198). Dordrecht: Springer.

Jost, T., Ouerhani, N., Wartburg, R. v., Müri, R., & Hügli, H. (2005). Assessing the contribution of color in visual attention. *Computer Vision and Image Understanding 100(1)*, 107-123.

Just, M. A., & Carpenter, P. A. (1980). A theory of reading: From eye fixations to comprehension. *Psychological Review*, 329-354.

Just, M., & Carpenter, P. (1971). Comprehension of negation with quantification. *Journal of Verbal Learning and Verbal Behavior, 10(3)*, 244-253.

Kamhi, A., & Catts, H. W. (1986). Toward an Understanding of Developmental Language and Reading Disorders. *The Journal of speech and hearing disorders 51(4)*, 337-347.

Kamide, Y., Altmann, G. T., & Haywood, S. L. (2003). The time course of prediction in incremental sentence processing: Evidence from anticipatory eye movements. *Journal of Memory and Language, 49*, 133−156.

Kamide, Y., Scheepers, C., & Altmann, G. T. (2003). Integration of syntactic and semantic information in predictive processing: Cross-linguistic evidence from German and English. *Journal of Psycholinguistic Research, 32*, 37−55.

Kaminen, N., & Hannula-Jouppi, K. (2003). A genome scan for developmental dyslexia confirms linkage to chromosome 2p11 and suggests a new locus on 7q32. *Journal of Medical Genetics, 40(5)*, 340-345.

Kamp, H. (1981). A theory of truth and semantic representation. *Formal Semantics-the Essential Readings*, 189-222.

Kamp, H., & Partee, B. (1995). Prototype theory and compositionality. *Cognition, 57*, 129-191.

Kaup, B. (1997). The processing of negatives during discourse comprehension. In M. G. Shafto, & P. Langley (Ed.), *Proceedings of the nineteenth conference of the cognitive science society.* Mahwah, NJ: Erlbaum.

Kaup, B. (2006). What psycholinguistic negation research tells us about the nature of the working-memory representations utilized in language comprehension. In H. Pishwa, *Language and Memory* (pp. 313-355). Berlin: Mouton de Gruyter.

Kaup, B., & Zwaan, R. (2003). Effects of negation and situational presence on the accessibility of text information. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29(3)*, 439–446.

Kaup, B., Lüdtke, J., & Zwaan, R. (2005). Effects of negation, truth value, and delay on picture recognition after reading affirmative and negative sentences. In B. G. Bara, & L. Barsal (Ed.), *Proceedings of the 27th*

Annual Conference of the Cognitive Science Society* (pp. 1114-1119). Mahwah, NJ: Lawrence Erlbaum.

Kaup, B., Lüdtke, J., & Zwaan, R. (2006). Processing negated sentences with contradictory predicates: Is a door that is not open mentally closed? *Journal of Pragmatics, 38*, 1033–1050.

Kaup, B., Lüdtke, J., & Zwaan, R. A. (2007). The experiential view of language comprehension: How is negation represented? In F. Schmalhofer, & C. A. Perfetti, *Higher level language processes in the brain. Inference and comprehension processes.* (pp. 255–288). London: Lawrence Erlbaum Associates.

Kaup, B., Yaxley, R. H., Madden, C. J., Zwaan, R. A., & Lüdtke, J. (2007). Experiential simulations of negated text information. *Quarterly journal of experimental psychology, 60(7)*, 976-990.

Kayne, R. S. (1989). Null subject and clitic climbing. In *The null subject parameter* (pp. 239-261). Springer: Dordrecht.

Khemlani, S., Orenes, I., & Johnson-Laird, P. N. (2012). Negation: A theory of its meaning, representation, and use. *Journal of Cognitive Psychology, 24,* 541-559.

Kim, D. (2010). The Interactive Effects of Colors on Visual Attention and Working Memory: In Case of Images of Tourist Attractions. *International CHRIE Conference.* Amherst, MA: ScholarWorks@UMass Amherst.

Kim, J. H., & Christianson, K. (2013). Sentence complexity and working memory effects in ambiguity resolution. *Journal of Psycholinguistic Research, 42(5)*, 393-411.

Kintsch, W. (1988). The role of knowledge in discourse comprehension: A construction-integration model. *Psychological Review, 95(2)*, 163–182.

Kintsch, W., & Dijk, T. v. (1978). Toward a model of text comprehension and production. *Psychological Review, 85(5)*, 363-394.

Klein, W. (2006). On finiteness. In *Semantics in acquisition* (pp. 245-272). Dordrecht: Springer.

Klima, E. S. (1964). Negation in English. In J. A. Fodor, & J. Katz, *The Structure of Language. Readings in the Philosophy of Language* (pp. 246-323). Englewoods Cliffs, NJ: Prentice-Hall.

Klima, E., & Bellugi, U. (1966). Syntactic Regularities in the Speech of Children. In *Psycholinguistic papers* (pp. 183-208). Edinburgh: Lyons and Waves.

Klingberg, T., Hedehus, M., & Temple, E. (2000). Microstructure of temporo-parietal white matter as a basis for reading ability: evidence from diffusion tensor magnetic resonance imaging. *Neuron, 25*, 493-500.

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. (2017). LmerTest: Tests in linear mixed effects models. *Journal of Statistical Software, 82(13)*.

Labov, W. (1972). Negative attraction and negative concord in English grammar. *Language*, 773-818.

Ladusaw, W. A. (1992). Expressing negation. *Semantics and linguistic theory, 2*, 237-260.

Ladusaw, W. A. (1996). Negation and polarity items. In S. Lappin, *The Handbook of Contemporary Semantic Theory.* Oxford: Blackwell Publishers.

Laka, I. (1990). *Negation in Syntax: on the Nature of Functional Categories and Projections.* MIT.

Leclercq, A. L., & Majerus, S. (2010). Serial-order short-term memory predicts vocabulary development: Evidence from a longitudinal study. *Developmental Psychology, 46(2)*, 417-427.

Leech, G. (1981). Pragmatics and conversational rhetoric. In H. Parrett, M. Sbisà, & J. Verschueren, *Possibilities and limitations of pragmatics.* Amsterdam: Benjamins.

Lehrer, A. (1985). Is semantics perception-driven or network-driven? *Australian Journal of Linguistics, 5(2)*, 197-207.

Leikin, M., & Hagit, E. Z. (2006). Morphological Processing in Adult Dyslexia. *Journal of Psycholinguistic Research, 35*, 471-490.

Leong, C. K., & Ho, M. K. (2012). Training orthographic and sentence structures help poor readers in Chinese. *International Journal of Disability, Development and Education, 59(4)*, 359-378.

Liuzza, M. T., Candidi, M., & Aglioti, S. M. (2011). Do not resonate with actions: sentence polarity modulates cortico-spinal excitability during action-related sentence reading. *PloS One, 6(2)*.

Luca, M. D., Pace, E. D., Judica, A., Spinelli, D., & Zoccolotti, P. (1999). Eye movement patterns in linguistic and non-linguistic tasks in developmental surface dyslexia. *Neuropsychologia, 37(12)*, 1407-1420.

Lüdtke, J., & Kaup, B. (2006). Context effects when reading negative and affirmative sentences. In R. Sun (Ed.), *Proceedings of the 28th Annual Conference of the Cognitive Science Society.* Mahwah, NJ: Lawrence Erlbaum.

Lüdtke, J., Friedrich, C. K., Filippis, M. D., & Kaup, B. (2008). Event-related potential correlates of negation in a sentence–picture verification paradigm. *Journal of Cognitive Neuroscience, 8*, 1355–1370.

MacDonald, M. C., & Just, M. A. (1989). Changes in activation level with negation. *Journal of Experimental Psychology: Learning, Memory and Cognition, 15*, 633-642.

MacDonald, M. C., Pearlmutter, N. J., & Seidenberg, M. S. (1994). The lexical nature of syntactic ambiguity resolution. *Psychological Review, 101*, 676−703.

Mackworth, N. H. (1968). The wide angle reflection eye camera for visual choice and pupil size. *Perception & Psychophysics, 3*, 32-34.

Magnuson, J. S., Dixon, J. A., Tanenhaus, M. K., & Aslin, R. N. (2007). The dynamics of lexical competition during spoken word recognition. *Cognitive Science, 31*, 1-24.

Magnuson, J. S., Tanenhaus, M. K., Aslin, R. N., & Dahan, D. (2003). The time course of spoken word learning and recognition: Studies with artificial lexicon. *Journal of Experimental Psychology: General, 132*, 202-227.

Mahon, B., & Caramazza, A. (2008). A critical look at the embodied cognition hypothesis and a new proposal for grounding conceptual content. *Journal of Physiology, 102(1-3)*, 59-70.

Majerus, S., Poncelet, M., Van der Linden, M., & Weekes, B. S. (2008). Lexical learning in bilingual adults: the relative importance of short-term memory for serial order and phonological knowledge. *Cognition, 107(2)*, 395-419.

Mak, W. M., Tribushinina, E., & Andreiushina, E. (2013). Semantics of connectives guides referential expectations in discourse: an eye-tracking study of Dutch and Russian. *Discourse Processes, 50(8)*, 557-576.

Mani, N., & Huettig, F. (2014). Word reading skill predicts anticipation of upcoming spoken language input: A study of children developing proficiency in reading. . *Journal of Experimental Child Psychology, 126*, 264-279.

Mann, V. A., Shankweiler, D., & Smith, S. T. (1984). The association between comprehension of spoken sentences and early reading ability: the role of phonetic representation. *Journal of Child Language, 11*, 627-643.

Manzini, M. R., & Savoia, L. M. (2005). *dialetti italiani e romanci: L'ausiliare (2a parte); La negazione e l'avverbio; Strutture aspettuali e modali; Il sintagma nominale.* Edizioni dell'Orso.

Marian, V., & Spivey, M. (2003 a). Bilingual and monolingual processing of competing lexical items. *Applied Psycholinguistics, 24*, 173-193.

Marian, V., & Spivey, M. (2003 b). Competing activation in bilingual language processing: Within- and between- language competition. *Bilingualism: Language and Cognition, 6*, 97-115.

Marslen-Wilson, W. D. (1987). Functional parallelism in spoken word recognition. *Cognition, 25*, 71-102.

Marslen-Wilson, W., & Welsh, A. (1978). Processing interactions and lexical access during word recognition in continuous speech. *Cognitive Psychology, 10*, 29-63.

Martin, K. (2013). *Developmental dyslexia and foreign language learning. A working memory approach. Doctoral dissertation.* Verona: University of Verona.

Matin, E., Shao, K. C., & Boff, K. R. (1993). Saccadic overhead: Information processing time with and without saccades. *Perception & Psychophysics, 53*, 372-380.

Matin, E., Shao, K. C., & Boff, K. R. (1993). Saccadic overhead: Information-processing time with and without saccades. *Perception & Psychophysics, 53*, 372-380.

Mayo, R., Schul, Y., & Burnstein, E. (2004). “I am not guilty” vs “I am innocent”: Successful negation may depend on the schema used for its encoding. *Journal of Experimental Social Psychology, 40(4)*, 433–449.

McClelland, J. L., & Elman, J. L. (1986). The TRACE model of speech perception. *Cognitive Psychology, 18*, 1-86.

McKoon, G., & Ratcliff, R. (1992). Inference during reading. *Psychological Review, 99(3)*, 433–449.

McLoughlin, D., Fitzgibbon, G., & Young, V. (1994). *Adult dyslexia: Assessment, counselling and training.* London: Whurr.

McLoughlin, D., Leather, C., & Stringer, P. (2002). *The adult dyslexic: interventions and outcomes.* London: Whurr.

McNeill, M. (1968). What does a child mean when he says no? *Proceedings of the Conference on Language and Language Behavior* (pp. 51-62). New York: Appleton-Century-Crofts.

McQueen, J. M., & Viebahn, M. C. (2007). Tracking recognition of spoken words by tracking looks to printed words. *Quarterly Journal of Experimental Psychology, 60*, 661-671.

McRae, K., Spivey-Knowlton, M. J., & Tanenhaus, M. K. (1998). Modeling the influence of thematic fit (and other constraints) in online sentence comprehension. *Journal of Memory and Language, 38*, 283−312.

Menghini, D., Finzi, A., Benassi, M., Bolzani, R., Facoetti, A., Giovagnoli, S., & Vicari, S. (2010). Different underlying neurocognitive deficits in developmental dyslexia: A comparative study. *Neuropsychologia, 48(4)*, 863-872.

Menghini, D., Finzi, A., Carlesimo, G. A., & Vicari, S. (2011). Working memory impairment in children with developmental dyslexia: Is it just a phonological deficit? *Developmental Neuropsychology, 36(2)*, 199-213.

Merchant, J. (2006). Why no(t)? *Style, 40 (1-2)*, 20-23.

Meyer, A. S., Sleiderink, A. M., & Levelt, W. J. (1998). Viewing and naming objects: Eye movements during noun phrase production. *Cognition, 66(2),* B25-B33.

Mitterer, H., & McQueen, J. M. (2009). Processing reduced word-forms in speech perception using probabilistic knowledge about speech production. *Journal of Experimental Psychology: Human Perception and Performance, 35*, 244-263.

Moeschler, J. (1992). The pragmatic aspects of linguistic negation: Speech act, argumentation and pragmatic inference. *Argumentation, 6(1)*, 51-76.

Moeschler, J. (2010). Negation, scope and the descriptive/metalinguistic distinction. *Generative Grammar in Geneva, 6*, 29-48.

Monaco, M., Costa, A., Caltagirone, C., & Carlesimo, G. A. (2013). Forward and backward span for verbal and visuo-spatial data: standardization and normative data from an Italian adult population. *Neurological Sciences, 34*, 749-754.

Montesano, L., Valenti, A., & Cornoldi, C. (2020). *LSC-SUA prove di lettura, comprensione del testo, scrittura e calcolo. Batteria per la valutazione dei DSA e altri disturbi in studenti universitari e adulti.* Erickson.

Morrow, D., Bower, G., & Greenspan, S. (1990). Situation-based inferences during narrative comprehension. *Psychology of Learning and Motivation, 25*, 123-135.

Murray, D. J. (1967). The role of speech responses in short-term memory. *Canadian Journal of Psychology, 21*, 263-276.

Nagy, Z., Westerberg, H., & Klingberg, T. (2004). Maturation of white matter is associated with the development of cognitive functions during childhood. *Journal of Cognitive Neuroscience, 16*, 1227-33.

Nation, K., Cocksey, J., Taylor, J. S., & Bishop, D. V. (2010). A longitudinal investigation of early reading and language skills in children with poor reading comprehension. *Journal of Child Psychology and Psychiatry, 51(9)*, 1031-1039.

Nicolson, R. I., & Fawcett, A. J. (1990). Automaticity: a new framework for dyslexia research? *Cognition, 35*, 159-182.

Nieuwland, M. S., & Kuperberg, G. R. (2008). When the truth is not too hard to handle. *Psychological Science, 19(12)*, 1213–1218.

Nilsen, Ø. (2003). *Eliminating positions: syntax and semantics of sentential modification.* Utrecht : Universiteit Utrecht.

Niogi, S. N., & McCandliss, B. D. (2006). Left lateralized white matter microstructure accounts for individual differences in reading ability and disability. *Neuropsychologia, 44*, 2178-88.

Norris, D. (1994). Shortlist: A connectionist model of continuous speech recognition. *Cognition, 52(3),* 189-234.

Norris, D., & McQueen, J. M. (2008). Shortlist B: A Bayesian model of continuous speech recognition. *Psychological Review, 115*, 357-395.

Orden, G. C., Johnston, J. C., & Hale, B. L. (1988). Word identification proceeds from spelling to sound to meaning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14*, 371-386.

Orenes, I., Beltrán, D., & Santamaría, C. (2014). How negation is understood: Evidence from the visual world paradigm. *Journal of Memory and Language, 74*, 36–45.

Orenes, I., Moxey, L., Scheepers, C., & Santamaría, C. (2015). Negation in context: Evidence from the visual world paradigm. *The Quarterly Journal of Experimental Psychology, 69 (6),* 1082-1092.

Ouhalla, J. (2003). *Functional categories.* Routledge.

Papeo, L., Hochmann, J., & Battelli, L. (2012). The default computation of negated meanings. *Journal of Cognitive Neuroscience, 28(12),* 1980-1986.

Paradis, C., & Willners, C. (2006). Antonymy and negation—The boundedness hypothesis. *Journal of Pragmatics, 38(7),* 1051–1080.

Partee, B. H. (1970). Negation, conjunction, and quantifiers: Syntax vs. Semantics. *Foundations of Language, 6(2),* 153-165.

Patterson, K., Nestor, P., & Rogers, T. (2007). Where do you know what you know? The representation of semantic knowledge in the human brain. *Nature Reviews Neuroscience, 8(12),* 976–987.

Paulesu, E., Démonet, J. F., Fazio, F., McCrory, E., Chanoine, V., Brunswick, N., & Frith, U. (2001). Dyslexia: Cultural diversity and biological unity. *Science, 291(5511),* 2165–2167.

Payne, J. R. (1985). Negation. *Language typology and syntactic description, 1,* 197-242.

Pea, R. (1980). The development of negation in early child language. In D. R. Olson, *The social foundations of language and thought* (pp. 156-186). New York: Norton & Company.

Peterson, R. L., & Pennington, B. F. (2012). Developmental dyslexia. *Lancet, 379 (9830)*, 1997-2007.

Philip, W., & Coopmans, P. (1996). The double Dutch delay of Principle B effect. In A. Stringfellow, D. Cahana-Amitay, & E. Hughes (Ed.), *Proceedings of the Annual Boston University Conference on Language Development, 20.* Somerville, MA: Cascadilla Press.

Pivi, M., & Del Puppo, G. (2014). L'acquisizione delle frasi relative restrittive in bambini italiani con sviluppo tipico e con dislessia evolutiva. *Atti del XIV Congresso AItLa.* Verona.

Plisson, A., Daigle, D., & Montésinon-Gelet, I. (2013). The Spelling Skills of French-Speaking Dyslexic Children. *Dyslexia, 19,* 79-91.

Poblano, A., Valadéz-Tepec, T., de Lourdes Arias, M., & García-Pedroza, F. (2000). Phonological and visuo-spatial working memory alterations in dyslexic children. *Archives of Medical Research, 31(5)*, 493-496.

Poletto, C. (2000). *The higher functional field.* Oxford: Oxford University Press.

Poletto, C. (2008). Parallel Phases: a study on the high and low left periphery of Old Italian. In *Phases of interpretation* (pp. 261-294). De Gruyter Mouton.

Pollock, J. Y. (1989). Verb Movement, Universal Grammar, and the Structure of IP. *Linguistic Inquiry, 20*, 365-424.

Postman, L., & Keppel, G. (1970). *Norms of word association.* New York: New York Academic Press.

Pulvermüller, F. A. (2002). Brain perspective on language mechanisms: From discrete neuronal ensembles to serial order. *Progress in Neurobiology, 67*, 85–111.

Pulvermüller, F., Kujala, T., Shtyrov, Y., Simola, J., Tiitinen, H., Alku, P., . . . Näätänen, R. (2001). Memory traces for words as revealed by the mismatch negativity. *NeuroImage, 14(3)*, 607-616.

Rack, J. P., Snowling, M. J., & Olson, R. K. (1992). The nonword reading deficit in developmental dyslexia: a review. *Reading Research Quarterly, 27*, 29-53.

Ramus, F., & Szenkovits, G. (2008). What phonological deficit? *The Quarterly Journal of Experimental Psychology, 61*, 129-141.

Ramus, F., Rosen, S., Dakin, S., & Day, B. (2003). Theories of developmental dyslexia: Insights from a multiple case study of dyslexic adults. *Brain, 126(4)*, 841-865.

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bullettin, 124(3)*, 372-422.

Re, A. M., Tressoldi, P. E., Cornoldi, C., & Lucangeli, D. (2011). Which Tasks Best Discriminate between Dyslexic University Students and Controls in a Transparent Language? *Dyslexia*, *17*, 227-241.

Reggiani, D. (2010). *Dyslexia and the acquisition of syntax: passive and control. Doctoral dissertation.* Verona: University of Verona.

Reinisch, E., Jesse, A., & McQueen, J. M. (2010). Early use of phonetic information in spoken word recognition: Lexical stress drives eye-movements immediately. *Quarterly Journal of Experimental Psychology, 63(4)*, 772-783.

Rispens, J. E. (2004). *Syntactic and phonological processing in developmental dyslexia. Doctoral dissertation.* Groningen: University of Groeningen.

Rispens, J., & Been, P. (2007). Subject-verb agreement and phonological processing in developmental dyslexia and specific language impairment (SLI): A closer look. *International Journal of Language & Communication Disorders, 42(3)*, 293-305.

Rizzi, L. (1982). *Issues in Italian Syntax.* Walter de Gruyter.

Roberts, C. (2012). Information structure in discourse: Towards an integrated formal theory of pragmatics. *Semantics and Pragmatics, 5(6),* 1-69.

Robertson, E. K., & Joanisse, M. F. (2009). Spoken sentence comprehension in children with dyslexia and language impairment: The roles of syntax and working memory. *Applied Psycholinguistics, 31(1)*.

Rommers, J., Meyer, A. S., Praamstra, P., & Huettig, F. (2012). The contents of predictions in sentence comprehension: Activation of the shape of objects before they are referred to. *Neuropsychologia*, *51*, 437-447.

Russell, B. (1905). On denoting. *Mind*, 479-493.

Salverda, A. P., & Tanenhaus, M. K. (2010). Tracking the time course of orthographic information in spoken-word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 36,* 1108-1117.

Scappini, M., Delfitto, D., Marzi, C. A., Vespignani, F., & Savazzi, S. (2015). On the non-incremental processing of negation: A pragmatically licensed sentence-picture verification study with Italian (dyslexic) adults. *Nouveaux cahiers de linguistique française 32 (2015)*, 45-58.

Scarborough, H. S. (1990). Very early language deficits in dyslexic children. *Child Development, 61*, 1728-1743.

Schlösser, R. G., Wagner, G., & Sauer, H. (2015). Assessing the working memory network: studies with functional magnetic resonance imagining and structural equation modeling. *Neuroscience*, *139,* 91-103.

Searle, J. R. (1969). *Speech Acts. An Essay in the Philosophy of Language.* Cambridge: Cambridge University Press.

Sedivy, J. C. (2003). Pragmatic versus form-based accounts of referential contrast: Evidence for effects of informativity expectations. *Journal of Psycholinguistic Research, 32(1)*, 3-23.

Sedivy, J. C. (2005). Evaluating explanations for referential context effects: Evidence for Gricean meachanisms in online language interpretation. In J. C. Trueswell, & M. K. Tanenhaus, *Approaches to Studying World-Situated Language Use: Bridging the Language-as-Product and Language-as-Action Traditions* (pp. 345-364). Cambridge, MA: MIT Press.

Sedivy, J. C., Tanenhaus, M. K., Chambers, C. G., & Carlson, G. N. (1999). Achieving incremental semantic interpretation through contextual representation. *Cognition, 71(2)*, 109-147.

Seymour, P. H., Aro, M., & Erskine, J. M. (2003). Foundation literacy acquisition in European orthographies. *British Journal of Psychology, 94*, 143-174.

Shaywitz, S. E., & Shaywitz, B. A. (2005). Dyslexia (Specific Reading Disability). *Biological Psychiatry, 57*, 1301-1309. Retrieved from International Dyslexia Association.

Sheldon, A. (1974). The role of parallel function in the acquisition of relative clauses in English. *Journal of Verbal Learning and Verbal Behavior, 13*, 272–281.

Slobin, D. I. (1985). Crosslinguistic evidence fort the Language Making Capacity. In *The crosslingustic study of language acquisition volume 2: theoretical issues* (pp. 1157-1249). Lawrence Erlbaum Associates Publishers.

Smith-Spark, J. H., & Fisk, J. E. (2007). Working memory functioning in developmental dyslexia. *Memory, 15(1)*, 34-56.

Snedeker, J., & Trueswell, J. C. (2004). The developing constraints on parsing decisions: The role of lexical-biases and referential scenes in child and adult sentence processing. *Cognitive Psychology, 49(3)* , 238−299.

Snowden, R. J. (2002). Visual Attention to Color: Parvocellular Guidance of Attentional Resources? *Psychological Science, 13(2)*, 180-184.

Snowling, M. (2000). *Dyslexia.* Oxford: Blackweel Publishers.

Snowling, M. J. (1995). Phonological processing and developmental dyslexia. *Journal of Research in Reading, 18*, 132-138.

Snowling, M. J., Gallagher, A., & Frith, U. (2003). Family risk of dyslexia is continuous: Individual differences in the precursors of reading skill. *Child Development, 74*, 358-373.

Spivey, M. J., & Marian, V. (1999). Cross talk between native and second languages: Partial activation of an irrelevant lexicon. *Psychological Science*, *10*, 281-284.

Sprouse, J., Wagers, M., & Phlips, C. (2012). Working-memory capacity and islands effect: A reminder of the issues and the facts. *Language, 88(2),* 401-407.

Staab, J., Urbach, T. P., Kutas, M., Alexandre, J., Schleicher, E., & Bates, E. (2008). Negation processing in context is not (always) delayed. *CRL Technical Report, 20(3)*.

Stanovich, K. E., & Siegel, L. S. (1994). Phenotypic performance profile of children with reading disabilities: A regression-based test of the phonological-core variable-difference model. *Journal of Educational Psychology, 86,* 24-53.

Stein, C. L., Cairns, H. S., & Zurif, E. B. (1984). Sentence comprehension limitations related to syntactic deficits in reading-disabled children. *Applied Psycholinguistics, 5,* 305-322.

Stein, J. (2001). The magnocellular theory of developmental dyslexia. *Dyslexia, 7(1),* 12-36.

Stein, J., & Walsh, V. (1997). To see but not to read: The magnocellular theory of dyslexia. *Trends in Neurosciences, 20(4),* 147-152.

Stella, G., Franceschi, S., & Savelli, E. (2009). Disturbi associati nella dislessia evolutiva: uno studio preliminare. *Dislessia*, 31-49.

Stern, G. (1937). *Meaning and Change of Meaning.* Bloomington: Indiana University Press.

Stoodley, C. J., Harrison, E. P., & Stein, J. F. (2006). Implicit motor learning deficits in dyslexic adults. *Neuropsychologia, 44*, 795-798.

Strawson, P. F. (1950). On referring. *Mind, 59*, 320-344.

Strawson, P. F. (1964). Identifying reference and truth values. *Theoria, 30,* 96-118.

Swanson, H. (1999). Reading comprehension and working memory in learningdisabled readers: Is the phonological loop more important than the executive system? *Journal of Experimental Child Psychology, 72(1)*, 1-31.

Szabolcsi, A. (2004). Positive polarity–negative polarity. *Natural Language & Linguistic Theory, 22(2)*, 409-452.

Tanenhaus, M. K., Spivey-Knowlton, M. J., Eberhard, K. M., & Sedivy, J. C. (1995). Integration of visual and linguistic information in spoken language comprehension. *Science, 268,* 1632-1634.

Tettamanti, M., & Buccino, G. (2005). Listening to action-related sentences activates fronto-parietal motor circuits. *Journal of Cognitive Neuroscience*, *17(2)*, 273–281.

Tettamanti, M., Manenti, R., Della Rosa, P., Falini, A., Perani, D., Cappa, S. F., & Moro, A. (2008). Negation in the brain: Modulating action representations. *NeuroImage*, *43(2)*, 358–67.

Thompson, C. K., & Choy, J. J. (2009). Pronominal resolution and gap filling in agrammatic aphasia: Evidence from eye movements. *Journal of Psycholinguistic Research*, *38*, 255-283.

Thompson-Schill, S. L., Kurtz, K. J., & Gabrieli, J. D. (1998). Effects of semantic and associative relatedness on automatic priming. *Journal of Memory and Language, 38(4)*, 440-458.

Tian, Y., Breheny, R., & Ferguson, H. (2010). Why we simulate negated information: A dynamic pragmatic account. *The Quarterly Journal of Experimental Psychology*, *63(12)*, 2305–2312.

Tian, Y., Ferguson, H., & Breheny, R. (2016). Processing negation without context—Why and when we represent the positive argument. *Language, Cognition and Neuroscience, 31(5)*, 683–698.

Tighe, E. L., & Binder, K. S. (2015). An investigation of morphological awareness and processing in adults with low literacy. *Applied Psycholinguistics, 36*, 245-273.

Tomasino, B., Weiss, P. H., & Fink, G. R. (2010). To move or not to move: Imperatives modulate action-related verb processing in the motor system. *Neuroscience*, *169(1)*, 246–58.

Trabasso, T., Rollins, H., & Shaughnessy, E. (1971). Storage and verification stages in processing concepts. *Cognitive Psychology, 2(3)*, 239–289.

Tribushinina, E., & Mak, W. M. (2016). Three-year-olds can predict a noun based on an attributive adjective: Evidence from eye-tracking. *Journal of Child Language*, *43(2)*, 425-441.

Trueswell, J. C., Sekerina, I., Hill, N. M., & Logrip, M. L. (1999). The kindergarten-path effect: Studying on-line sentence processing in young children. *Cognition, 73*, 89-134.

Trueswell, J. C., Tanenhaus, M. K., & Garnsey, S. M. (1994). Semantic influences on parsing: The use of thematic role information in syntactic ambiguity resolution. *Journal of Memory and Language, 33*, 285−318.

Trueswell, J., & Gleitman, L. R. (2004). Children's eye movements during listening: Evidence for a constraint-based theory of parsing and word learning. In J. M. Henderson, & F. Ferreira, *Interface of language, vision,* *and action: Eye movements and the visual world* (p. 319−346). NY: Psychology Press.

Tyler, L. K., & Marslen-Wilson, W. D. (1977). The on-line effects of semantic context on syntactic processing. *Journal of Verbal Learning of Verbal Behavior, 16*, 683-692.

Van Valin, R. (1991). Functionalist linguistic theory and language acquisition. *First Language, 11(31)*, 7-40.

Vellutino, F. R., Fletcher, J. M., Snowling, M. J., & Scanlon, D. M. (2004). Specific reading disability (dyslexia): what have we learned in the past four decades? *Journal of Child Psychology and Psychiatry, 45*, 2-40.

Vender, M. (2011). *Disentangling dyslexia. Phonological and processing impairment in developmental dyslexia.* University of Verona: Doctoral dissertation.

Vender, M. (2017). *Disentangling Dyslexia - Phonological and Processing Impairment in Developmental Dyslexia* (Vol. Linguistic Insights). (M. Gotti, Ed.) Peter Lang.

Vender, M., & Delfitto, D. (2010). Towards a pragmatic of negation: The interpretation of negative sentences in Developmental Dyslexia. *GG@G – Generative Grammar at Geneva*, 5–32.

Villiers, J. G., & Flusberg, H. B. (1975). Some facts one simply cannot deny. *Journal of Child Language, 2*, 279-286.

Vinegrad, M. (1994). A revised adult dyslexia checklist. *Educare, 48*.

Wales, R. J., & Grieve, R. (1969). What is so difficult about negation? *Perception & Psychophysics, 6(6)*, 327-332.

Walsh, M., Dickey, J. J., Choy, J. W., & Thompson, C. K. (2007). Real-time comprehension of wh- movement in aphasia: Evidence from eyetracking while listening. *Brain and Language, 100*, 1-22.

Waltzman, D., & Cairns, H. (2000). Grammatical knowledge of third grade good and poor readers. *Applied Psycholinguistics, 21*, 263–284.

Wang, S., & Gathercole, S. E. (2013). Working memory deficits in children with reading difficulties: Memory span and dual task coordination. *Journal of Experimental Child Psychology, 115*, 188-197.

Warren, T., & Gibson, E. (2002). The influence of referential processing on sentence complexity. *Cognition, 85(1)*, 79-112.

Wason, P. (1959). The processing of positive and negative information. *Quarterly Journal of Experimental Psychology, 11*, 92-107.

Wason, P. (1961). Response to affirmative and negative binary statements. *British Journal of Psychology, 52(2),* 133–142.

Wason, P. (1965). The contexts of plausible denial. *Journal of Verbal Learning and Verbal Behaviour, 4(1),* 7-11.

Wason, P. C., & Jones, S. (1963). Negatives: Denotation and connotation. *British Journal of Psychology*, 299-307.

Weber, A., & Cutler, A. (2004). Lexical competition in non-native spoken-word recognition. *Journal of Memory and Language*, *50*, 1-25.

Weber, A., Melinger, A., & Tapia, L. L. (2007). The mapping of phonetic information to lexical representation in Spanish: Evidence from eye movements. *Proceedings of the 16th International Congress of Phonetic Sciences (ICPhS 2007)* (pp. 1941-1944). Dudweiler: Pirrot.

Weissenborn, J., Verrips, M., & Berman, R. (1989). *Negation as a window to the structure of early child language.* Nijmegen: ms.

Willburger, E., Fussenegger, B., Moll, K., Wood, G. M., & Landerl, K. (2008). Naming speed in dyslexia and dyscalculia. *Learning and Individual Differences*, *18(2),* 224-236.

Wilson, A. M., & Lesaux, N. K. (2001). Persistence of Phonological Processing Deficits in College Students with Dyslexia Who Have Age-Appropriate Reading Skills. . *Journal of Learning Disabilities, 34(5),* 394-400.

Wimmer, H. (1993). Characteristics of developmental dyslexia in a regular writing system. *Applied Psycholinguistics, 14*, 1-33.

Wimmer, H., & Goswami, U. (1994). The influence of orthographic consistency on reading development-word recognition in English and German children. *Cognition, 51*, 91-103.

Wiseheart, R., Altmann, L. J., Park, H., & Lombardino, L. J. (2009). Sentence comprehension in young adults with developmental dyslexia. *Annals of Dyslexia, 59(2),* 151-167.

Wode, H. (1977). Four early stages in the development of L1 negation. *Journal of Child Language, 4,* 87-102.

Wolf, M., & Obregón, M. (1992). Early naming deficits, developmental dyslexia, and a specific deficit hypothesis. *Brain and Language, 42,* 219-247.

Wolf, M., Bally, H., & Morris, R. (1986). Automaticity, retrieval processes, and reading: A longitudinal study in average and impaired readers. *Child Development, 57*, 988-1000.

Wolf, M., Bowers, P. G., & Biddle, K. (2000). Naming speed processes, timing, and reading: a conceptual review. *Journal of Learning Disabilities, 33*, 387-407.

Wolfe, J. M., & Horowitz, T. S. (2004). What Attributes Guide the Deployment of Visual Attention and How Do They Do It? *Nature reviews Neuroscience 5(6)*, 495-501.

World Health Organization. (2004). *International statisical classification of diseases and health related problems. ICD-10.* Geneva, Switzerland.

Wouden, T. v. (1994). Polarity and 'illogical negation'. *Dynamics, Polarity and Quantification, 17*, 16-45.

Yee, E., & Sedivy, J. C. (2006). Eye movements to pictures reveal transient semantic activation during spoken word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32*, 1-14.

Yee, E., Blumstein, S. E., & Sedivy, J. C. (2008). Lexical-semantic activation in Broca's and Wernicke's aphasia: Evidence from eye movements. *Journal of Cognitive Neuroscience, 20*, 592−612.

Yee, E., Huffstetler, S., & Thompson-Schill, S. L. (2009). *Function follows form: Activation of shape & function features during concept retrieval.* Poster presented at the 50th Annual Meeting of the Psychonomic Society.

Young, L. R., & Sheena, D. (1975). Survey of eye movement recording methods. *Behavior Research Methods & Instrumentation, 7*, 397-429.

Zanuttini, R. (1997). *Negation and clausal structure. A comparative study of Romance languages.* New York: Oxford University Press.

Zanuttini, R. (2001). Sentential negation. In M. Baltin, & C. Collins, *The Handbook of Contemporary Syntactic Theory* (pp. 511-535). Blackweel Publishers.

Zeijlstra, H. (2004). *Sentential negation and negative concord.* Utrecht: LOT.

Zeijlstra, H. (2006). The ban on true negative imperatives. *Empirical issues in syntax and semantics, 6*, 405-424.

Zeijlstra, H. (2007). Negation in Natural Language: On the Form and Meaning of Negative Elements. *Language and Linguistics Compass, 1(5),* 498-518.

Zeijlstra, H. (2008). On the syntactic flexibility of formal features. In *The limits of syntactic variation* (pp. 143-174).

Zeijlstra, H. (2009). On French negation. *Annual Meeting of the Berkeley Linguistics Society, 35(1)*, 447-458.

Zeijlstra, H. (2013). Negation and negative polarity. In M. D. Dikken, *The Cambridge Handbook of Generative Syntax* (pp. 793-826). Cambridge: Cambridge University Press.

Zeijlstra, H. (2013). Not in the first place. *Natural Language and Linguistic Theory, 31(3)*, 865-900.

Ziegler, J. C., Perry, C., Ma-Wyatt, A., Ladner, D., & Schulte-Körne, G. (2003). Developmental dyslexia in different languages: Language-specific or universal? *Journal of Experimental Child Psychology 86*, 169-193.

Zwaan, R. (2004). The immersed experiencer: Toward an embodied theory of language comprehension. In B. H. Ross, *The Psychology of Learning and Motivation* (pp. 35-62). New York: Academic Press.

Zwaan, R. A., & Taylor, L. J. (2006). Seeing, acting, understanding: Motor resonance in language comprehension. *Journal of Experimental Psychology: General, 135(1)*, 1-11.

Zwaan, R., & Radvansky, G. (1998). Situation models in language comprehension and memory. *Psychological Bulletin, 123(2)*, 162-185.

Curriculum Vitae

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Place and date of Birth: Brescia (BS), Italy – August 28th, 1991

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EDUCATION

2017- current

University of Verona & Georg-August Universität Göttingen

Joint PhD track in Linguistics

Research Project: *On vision and language interaction in negation processing. The real-time interpretation of sentential negation in typically developed and dyslexic adults.*

Supervisor: Prof. Chiara Melloni (UNIVR), Prof. Dr. Hedde Zeijlstra (UGOE)

2014-2016

University of Verona

M.A. in Linguistics cum laude

Thesis title: *The acquisition of Double Negation in Italian. An experimental study.* Supervisor: Prof. Dr. Denis Delfitto and Prof. Chiara Melloni

2010-2013

University of Bergamo

B.A. in Communication Sciences

TEACHING EXPERIENCE

a.y. 2018/2019-a.y. 2021/2021 - University of Verona

Morpho-syntax. 20 hours. Teaching assistant

a.y. 2019/2020-a.y. 2020/2021 - University of Verona [invited lecture] Experimental research on language processing: the acquisition of syntax for the General Linguistics course (Prof. Chiara Melloni)

CONFERENCE AND WORKSHOP PRESENTATIONS

2021

CIDSM15 15th Cambridge Italian Dialect Syntax-Morphology, September 8th-10th S 2021, University of Helsinki (Finland) Short talk (joint work with Jelena Zivojinovic – University of Verona/UiT Tromsø) "*Grammaticalization in northern Italo-Romance: some considerations"*

2020

GRAMM3 Third International Conference on Grammaticalization Theory and Data, March 23rd-24th 2020, University of Rouen (France) Talk (joint work with Jelena Živojinović – University of Verona UiT Tromsø) *"Grammaticalization in northern Italo-Romance: some considerations"* (postponed in 2021 due to covid-19 outbreak)

2019

Humanities in the third millennium: approaches, contaminations and perspectives, University of Verona October 17th-18th 2019. Talk (joint work with Jelena Živojinović– University of Verona UiT Tromsø) *"Grammaticalization in northern Italo-Romance: some considerations"*

Talk (joint work with Daniele Panizza – University of Göttingen): *"The saliency of the mentioned argument facilitates the processing of negation: a visual world study"* presented at: XPRAG.IT 2019 Experimental Pragmatics in Italy, Cagliari (Italy), September 19th-20th; AMLAP 2019 Architectures and Mechanisms for Language Processing, Moscow (Russia) September 6th-8th; BLL 2019 Brain, Language and Learning, Siena (Italy), September 26th-28th (poster)

CLSHEF19 Child Language Symposium, University of Sheffield (UK), July 10th-12th. Posters: *"The Acquisition of double negation in Italian"* & *"The role of semantic plausibility in the interpretation of ambiguous ORCs with post-verbal subject in Italian".*

EPC 2019 Experimental Psycholinguistics Conference, Universidad Nacional de Educación a Distancia, Palma de Mallorca (Spain), June 26th-28th, Talk: *"The role of semantic plausibility in the interpretation of ambiguous ORCs with post-verbal subject in Italian".*

CLASTA 2019 Communication & Language Acquisition Studies in Typical & Atypical populations, University of Verona, May 10th-11th. Poster: *"L'apprendimento della doppia negazione in Italiano L1"*

2018

LAVA Seminar, University of Tromsø, October 25th. Talk: *"Is semantic plausibility a clue to the interpretation of ambiguous ORCs with post-verbal subject in Italian?".*

AMBIGO 2018 Workshop on Ambiguity – Theory Development and Processing, Georg-August Universität, Göttingen (Germany), July 4-6. Poster presentation: *"The role of competitors in the online processing of negation."*

OLINCO 2018 Olomouc Linguistics Colloquium, Palacký University Olomouc (Czechia), June 7-9 Poster presentation: *"The acquisition of Double Negation in Italian"*

Verona & Nova Gorica AThEME Workshop. Talk: *"On vision and language interaction in negation processing. An eye tracking study."* University of Verona, January 25th.

CONFERENCE ORGANIZATION

October 17th-18th 2019 *Humanities in the third millennium: approaches, contaminations and perspectives*, University of Verona (organizing committee)

PUBLICATIONS

Tagliani M., Vender M., and Melloni C. (2021) Object relatives with postverbal subject in Italian-speaking children and adults: The role of encyclopedic knowledge in detecting sentence ambiguity, *Language Acquisition*, DOI: 10.1080/10489223.2021.1914623

Tagliani, M. (2019). The Role of Semantic Plausibility in the Interpretation of Ambiguous Object Relative Clauses with Post-Verbal Subject in Italian. *Words*, 1, 9-10.

Tagliani, M. (2019). The Acquisition of Double Negation in Italian. In Joseph Emonds, Markéta Janebová, and Ludmila Veselovská, (eds). *Language Use and Linguistic Structure. Proceedings of the Olomouc Linguistics Colloquium* 2018, 109-126. Olomouc: Palacký University

Tagliani M., Canciani V., & Tommasi F. (eds), *Humanities in the third millennium: approaches, contaminations and perspectives*, Verona: Cierre Editore (2020)