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Primary and secondary stress in Italian and German

Position, weight-sensitivity and acoustic correlates

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Coordinator: **Prof. Stefan Rabanus**

Signature Stefan Rabanus

Coordinator: **Prof. Yvonne Zimmermann**

Signature Y. Zimmermann

Tutor: **Prof. Birgit Alber**

Signature Birgit Alber

Tutor: **Prof. Ulrike Domahs**

Signature ______________________

Doctoral Student: Andrea Brugnoli

Signature ______________________

Primary and secondary stress in Italian and German. Position, weight-sensitivity and acoustic correlates

Andrea Brugnoli
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Abstract

This dissertation aims, on the one hand, at investigating primary and secondary stress assignment in Italian and German, specifically with respect to the influence of syllable weight; on the other hand, it aims at investigating the acoustic correlates of primary and secondary stress in the same two languages.

In order to analyze primary and secondary stress assignment and the influence of syllable weight, for each of the investigated languages, a nonce word experiment and a corpus analysis have been carried out, analyzing how primary and secondary stress position is influenced by a variety of syllable structures.The results indicate that, both in Italian and German, syllable weight plays a role with respect to primary and secondary stress assignment, although in different ways between the two languages.

In order to analyze the acoustic correlates of primary and secondary stress, for each of the investigated languages, a production experiment has been conducted. The results indicate that in, the case of Italian, duration and F1 can be considered reliable correlates of primary stress, while F0 might be considered a reliable correlate of secondary stress. In the case of German, duration, F0, F1 and F2 can be considered reliable correlates of both primary and secondary stress, while spectral tilt can be considered a reliable correlate only of primary stress.

Sommario

Questa dissertazione mira, da un lato, ad investigare l'assegnazione dell'accento primario e secondario in italiano e tedesco, specificamente per quanto riguarda l'influenza del peso sillabico; dall'altro lato, mira ad investigare i correlati acustici dell'accento primario e secondario nelle medesime due lingue.

Al fine di analizzare l'assegnazione dell'accento primario e secondario e l'influenza del peso sillabico, per ciascuna delle lingue investigate è stato condotto un esperimento con non-parole e un'analisi su corpus, analizzando il modo in cui la posizione dell'accento primario e secondario viene influenzata da diversi tipi di strutture sillabiche. I risultati indicano che, sia in italiano che in tedesco, il peso sillabico gioca un ruolo determinante rispetto all'assegnazione dell'accento primario e secondario, sebbene in modo diverso tra le due lingue.

Al fine di analizzare i correlati acustici dell'accento primario e secondario, per ciascuna delle lingue investigate è stato condotto un esperimento di produzione. I risultati indicano che, nel caso dell'italiano, la durata e F1 possono essere considerati correlati dell'accento primario, mentre F0 può essere considerato un correlato dell'accento secondario. Nel caso del tedesco, la durata, F0, F1 e F2 possono essere considerati correlati sia dell'accento primario che di quello secondario, mentre lo spectral tilt può essere considerato un correlato solo dell'accento primario.

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Any errors and misconceptions are my sole responsibility.

Abbreviations

A	antepenultimate syllable
C	consonant
F	final syllable
G	glide
V	vowel
VV	long vowel
H	heavy syllable
L	light syllable
μ	mora
P	penultimate syllable
PS	primary stress
SS	secondary stress
σ	any type of syllable
x́ (acute accent)	primary stress
x̀ (grave accent)	secondary stress
X	any syllable other than the primary stressed syllable
Y	primary stressed syllable

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1 Introduction

The aim of this thesis is to provide novel data concerning the stress systems of Italian and German. More specifically, the first part of the thesis is aimed at analyzing experimentally how primary and secondary assignment in these two languages works, especially with respect to the influence of syllable weight, which is known to play a role in both languages. The second part of the thesis is aimed at analyzing how primary and secondary stress in Italian and German are realized from an acoustic point of view.

Concerning the first part, with respect to primary stress assignment and the influence of syllable weight on primary stress in German, more experimental data have been gathered so far in comparison to Italian, for which little experimental evidence is available. With respect to secondary stress assignment and the influence of syllable weight on secondary stress, in the case of both Italian and German little research has been conducted, so that the present work is especially aimed at providing novel results with respect to this issue.

With respect to Italian, primary stress is usually assumed to be restricted to the last three syllables of a word and to have a default position on the penultimate syllable. The weight of the penultimate syllable is also assumed to play the major role with respect to stress assignment, since a heavy penult with a consonant in the coda (CVC) attracts stress. However, the influence of a heavy antepenult on stress assignment remains unclear, as well the influence of other types of heavy syllables besides a syllable with a consonant in the coda.[1]

Secondary stress in Italian is thought to have a directionality from left to right, i.e. having the default position on the first syllable of a word and building a disyllabic trochee, as in $(\grave{\sigma}\sigma)\sigma\acute{\sigma}$. However, not much experimental evidence has been provided so far in support of this hypothesis. With respect to the possible influence of syllable weight on secondary stress, to my knowledge no extensive study has been conducted so far, so that this thesis is aimed at shedding some light on the issue of whether, besides primary stress, also secondary stress in Italian is sensitive to syllable weight, and, if so, how the sensitivity to syllable weight might differ between the two levels of stress.

With respect to German, as in the case of Italian, primary stress is restricted to the last three syllables of a word and it is assumed to have a default position on the penultimate syllable. Contrary to Italian, more experimental evidence has been provided in German, especially with respect to the influence of syllable weight on primary stress. The weight of the final syllable has been found to

[1] The weight of the final syllable is not usually taken into consideration in the literature, since, apart from loanwords, the final syllable in the Italian lexicon is usually a light syllable (CV).

play the major role with respect to primary stress assignment, since a word with a final heavy syllable with a consonant in the coda (CVC) has been found to be stressed most frequently on the final or on the antepenult, while a final syllable with two consonants in the coda (CVCC) attracts stress more than a syllable with a consonant in the coda (CVC), thus counting as a superheavy syllable. However, the influence of syllable weight in the penultimate and antepenultimate syllable has not been extensively investigated, as well as the possible influence of other types of heavy syllables besides a syllable with a consonant in the coda (CVC).

Secondary stress in German, as in the case of Italian, is thought to have a directionality from left to right, i.e. having the default position on the first syllable of a word and building a disyllabic trochee, as in (σ̀σ)σσ́. Although some evidence suggests a possible influence of syllable weight on secondary stress, no extensive research has been conducted on this issue and on how exactly the influence of syllable weight on secondary stress might differ from the influence of syllable weight on primary stress.

Another issue that is investigated in this thesis with respect to primary stress both in Italian and German is how stress assignment and syllable weight might interact with the tendency to achieve full parsing of a word into trochaic feet, i.e. the foot type which is traditionally associated with the metrical systems of these two languages. More specifically, the question that is investigated is whether, for instance, in a 4-syllable word of the LLLL type stress might tend to fall on the default penultimate syllable more often than in a 3-syllable word of the LLL type, since stressing the penult will allow to achieve full parsing into trochaic feet in the 4-syllable word, as in (L̀L)(ĹL), but not in the 3-syllable word, in which only the parsing (ĹL)L or L(ĹL) are possible.

In order to analyze primary and secondary stress assignment in Italian and German, the influence of syllable weight and the possible interaction with parsing, two methodologies are used.

The first methodology consists in a nonce word experiment, which allows to investigate the algorithm for stress assignment in these two languages, directly as it is represented in the speaker's *competence*, without the possible influence of external variables, such as morphology. The second methodology consists in a corpus analysis, which allows to observe the stress patterns in the lexicon. The corpus analysis is overall expected to corroborate the results of the nonce word experiment, although some differences between the two analyses might also be expected, due to the nature of the relationship between the phonological rules in the speaker's *competence* and how these rules are represented in the lexicon.

Concerning the acoustic correlates of stress in Italian and German, with respect to primary stress, in both languages duration has been found to be the strongest correlate, however, the role of other correlates remains unclear, especially for Italian. With respect to secondary stress, to my knowledge only one study has been conducted so far on Italian, suggesting spectral tilt as a possible acoustic correlate of secondary stress, while in the case of German, none of the few studies conducted so far has managed to single out some clear correlates of secondary stress.

In order to investigate how primary and secondary stress are realized from an acoustic point of view in Italian and German, two production experiments have been conducted in which speakers are recorded while reading real words with primary and secondary stress. In the analysis of the acoustic correlates of stress, some additional variables that might have an influence on the manifestation of the acoustic correlates of stress are also investigated, namely, stress position (in Italian), polysyllabic shortening (in German) and the length of the inter-stress interval between primary and secondary stress (in both Italian and German).

In order to analyze the above mentioned issues concerning stress in Italian and German, this thesis is divided into two main parts. the first part (Part 1) is dedicated to the analysis of primary and secondary stress assignment and the influence of syllable weight. Firstly, the relevant literature on stress and syllable weight is discussed in chapters (2-4), secondly, the nonce word experiments and the corpus analyses, each preceded by chapters discussing the main research questions, are presented in chapters (5-10). The second part of the thesis (Part 2), is dedicated to the analysis of the acoustic correlates of stress of primary and secondary stress. Firstly, the relevant literature concerning the acoustic correlates of stress is discussed in chapters (11-13), secondly, the experiments on the acoustic correlates of stress are presented in chapters (14-15), while chapter 16 provides some general conclusions and a comparison between the results of Italian and German.

Part 1

The influence of syllable weight on primary and secondary stress in Italian and German

2 Stress and syllable weight

2.1 Stress

This chapter aims at giving an overview of the concept of 'stress' mainly in the domain of phonology.[2] Firstly, a brief discussion will be dedicated to the different phonological phenomena which have to do with prosody and the relative terminology (e.g. stress and accent), secondly this chapter will deal more specifically with the prosodic unit which is the object of study in this thesis, i.e. word stress.

A first terminological distinction must be made between the terms *stress* and *accent*, both of which are used in the literature to refer to a type of prominence occurring in some kind of prosodic domain. The term *(word) stress* is usually employed to refer to some prominence at the lexical level, while the term *accent* is employed in at least two different ways: some authors (e.g. Fox 1999) use it to refer to an abstract concept of prominence, which in turn can have different phonetic manifestations, as in *stress-accent*, a prominence characterized mainly by a higher intensity or duration and *pitch-accent*, a prominence characterized mainly by pitch. Other authors reserve the term *stress* to prominence at the lexical domain and the term *accent* to prominence at the post-lexical domain, referring to the peak of prominence over a phrase or a sentence (Cutler 1984). In this thesis, the term *pitch-accent* will be used to refer to a type of prominence at the word level characterized mainly by pitch, such as the one which is found in languages like Japanese (see further below) while the expression *sentence accent* will be used to refer to prominence in the post-lexical domain.[3]

The first major distinction which will be addressed is the one between *word stress* and *sentence accent.* As anticipated, the first aspect of this distinction concerns the domain of application: while word stress refers to an increase in prominence within a word, i.e. within the lexical domain, sentence accent refers to an increase in prominence within a sentence or a phrase, i.e. within the syntactic or post-lexical domain. The two domains can be associated with the corresponding constituents in the prosodic hierarchy, which categorizes the different layers of speech at the prosodic level. The prosodic hierarchy can be analyzed as comprising the following domains, from the highest to the lowest (Nespor and Vogel 2007):

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[2] Chapter 13 is dedicated to the discussion of the phonetics of stress.

[3] It should be noted that also when referring to prominence in the post-lexical domain there is no unanimous label used in the literature. Other labels which are employed are, for example, *phrasal accent* (van der Hulst 2010), *phrasal stress* (Hayes 1995) or in the literature on intonation, *pitch accent*, in reference to the fact that the main phonetic correlate of the intonational contour is F_0 (Hirst & Di Cristo (1998).

(1) Phonological Utterance
Intonational Phrase
Phonological Phrase
Clitic Group
Phonological Word
Foot
Syllable

Taking the hierarchy in (1) as reference, sentence accent could be roughly associated with the levels above and including the clitic group, while word stress could be mainly associated with the phonological word and its sub-units, the foot and the syllable, both of which will be discussed in the subsequent paragraphs.

A second distinction that can be made concerns the different acoustic properties correlated with the two phenomena: while word stress is usually cued by changes in different parameters such as intensity, duration, fundamental frequency (from now on abbreviated as F_0) or formant frequencies, sentence accent is manifested mostly by changes in F_0 (although other acoustic parameters might still play a role) (Hirst & Di Cristo 1998).

Turning now to the lexical domain, i.e. to the phonological word, three kinds of prominence are usually distinguished: *(word) stress*, *pitch accent* and *tone*.

The term *word stress* is employed to refer to a type of prominence characterized by different acoustic parameters such as intensity, duration, F_0, spectral characteristics of vowels and others, among which usually only one or just a few function as the major cues. Phonetically, the locus of stress is often the vowel, or alternatively the syllable as a whole or its single segments (see also chapter 11). At least two levels of word stress are usually recognized: primary stress (also called main stress) and secondary stress. While primary stress refers to the main type of prominence within a word, secondary stress refers to an intermediate level of prominence lower than that of main stress and higher than that of an unstressed syllable, as in the word *lòcalizátion,* where primary stress falls on the penultimate syllable, while a secondary stress could be realized on the first syllable.

The term *pitch accent* refers to a type of prominence where the main acoustic correlate is represented by $F_{0,}$ phonologically referred to as *pitch*. However, a pitch accent system differentiates itself from a stress system also by other factors.[4] For example, unlike a stress system, a pitch accent system might include unaccented forms, as exemplified by Japanese *káki* 'oyster' (accented on the first syllable), *kakí* 'fence' (accented on the second syllable) and *kaki* 'persimmon' (unaccented). Furthermore, in an accented word in Japanese the higher pitch is not restricted to the accented syllable, but spreads also to the preceding syllables, which bear the same pitch level. Finally, in Japanese, in monosyllabic accented words the pitch contrast can be neutralized when such words stand by themselves, such as *hi* 'fire' and *hi* 'sun'. However, their contrast as accented or unaccented words emerges when they become disyllabic through suffixation, as in *híga* (accented) and *higa* (unaccented) respectively (Abe 1998). Within the pitch accent system, other languages are described as having a mixed system, where stress plays the major role but where some words also possess a specific pitch accent. Examples of this type are Norwegian, Swedish and Croatian.

The term *tone*[5] usually refers to a type of prominence characterized by changes in F_0, as in the case of a pitch accent. However, while a pitch accent is usually found on only one syllable of a word or spreads over more syllables (Haraguchi 1975), in tonal languages each syllable has its own tone, which can be distinctive, creating minimal pairs. Tones are divided into register tones, i.e. tones that are distinguished only by their relative height (e.g. high *vs* low tone) and contour tones, i.e. tones that are distinguished by their melodic pattern (e.g. rising *vs* falling). Example of tonal languages are Chinese and Vietnamese[6] (Hirst & Di Cristo 1998).

Typologically, an analysis made by Goedemans (2010) on a sample of 176 languages based on the WALS database (Dryer & Haspelmath 2013) reveals that 80% (141) of the surveyed languages has stress, 16% (28) has either tone or pitch accent and 4% was reported as having none of the above mentioned prosodic features.

The next two paragraphs will be dedicated to discuss in more detail the main object of study of this thesis, i.e. word stress, first discussing primary stress and then secondary stress.

[4] It has also been claimed by Hyman (2009) that pitch accent systems do not form a distinct prosodic class, rather they are found in languages that use prosodic properties of both tone and stress systems, representing thus an intermediate system between these two.

[5] The terms *pitch accent* and *tone* are also used with a different meaning in the domain of intonation, for example in the ToBi system (Silverman et al.1992), when referring to focal points and variations in the intonation contour. For instance, the pitch accents H and L describe a high and low tone, respectively.

[6] A tone system might not necessarily exclude the presence of stress, for example Kratochvil (1998) reports that Beijing Chinese , besides a five tone distinction, also shows a difference between stressed and unstressed syllables, in terms of parameters such as intensity and duration or in which the tonal patterns are neutralized in unstressed syllables.

2.2 Primary stress

Primary stress can be defined as the major prominence within a word. As anticipated in the previous paragraph, primary stress can be characterized phonetically by different cues such as intensity, duration, F_0 and others. Besides phonetic cues, primary stress can also be signaled by some phonological cues, such as allophonic variation. For instance, in English, word initial /p/ in onset position is realized as [p^h] in a stressed syllable (unless preceded by /s/), otherwise it is realized as [p] if the syllable is unstressed (van der Hulst 2005). Another example of a phonological phenomenon related to stress is vowel reduction. In English, certain stressed vowels are usually reduced to a schwa when they become unstressed, as in *telégraphy vs telegráphic* where the stressed /ɛ/ in the former is realized as /ə/ in the latter when becoming unstressed (Fourakis 1991).

Primary stress can also be identified by the fact that when a word is inserted into a larger domain of the prosodic hierarchy, such as in an intonational phrase, word stress can function as anchor point to the pitch accents[7] of the melodic contour (Gussenhoven 2007), as in the following example, where the pitch accents are indicated by H (high):

(2) Torónto is the cápital of Ontário.
H H

(adapted from Gussenhoven 2007: 269)

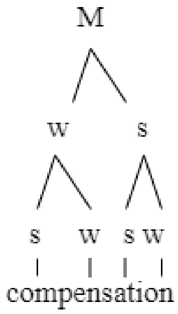
In the above example, the high pitches of the intonational contour overlap with the location of the primary stress of the word *Toronto* and *Ontario*.

In the phonological literature, stress has been described and represented in different ways. Chomsky and Halle (1968) analyzed stress as a property of single segments which is determined by a set of rules that apply in a cyclical fashion. Subsequently, Liberman and Prince (1977) in their theory of Metrical Phonology analyzed stress as a relational property represented by weak and strong branches organized in hierarchical structures, formally representable also through metrical grids, as in the following examples, which show the representation of the word *compensation*, first using a tree structure and then a metrical grid:

[7] When talking about intonation, the terms *pitch accent* and *tone* are used differently than when talking about the lexical domain (i.e. as in the case of the pitch accents in Japanese and the tones in Chinese). In the case of intonation, these terms refer to specific points (pitch levels) in the melodic contour of a specific prosodic constituent.

(3)

a.



b.

(adapted from Liberman and Prince 1977)

In both examples the stressed syllable is *sa*, which in the tree structure is represented as dominated only by strong nodes, while in the metrical grid it is represented with the highest number of asterisks. The syllable *com* is instead represented as having a lesser degree of stress than the syllable *sa* (i.e. bearing a secondary stress), by being ultimately dominated by a weak node in the tree structure and by having a lower number of asterisks in comparison with the primary stressed syllable in the metrical grid.

More recently, stress assignment has been formalized in the framework of Optimality Theory (Prince & Smolensky 1993), through which stress-assignment rules and the resulting stress typology are derived through the interactions of a set of universal constraints which can be ordered in different rankings. Among the various languages, OT analyses of stress have also been applied to Italian (Krämer 2009) and German (Alber 1997b, 1998, 2020, Féry 1998, Knaus & Domahs 2009).[8]

Since stress surfaces at least under two levels of prominence, primary and secondary, it follows that some words can potentially contain more than one stress and, in sufficiently long words, it may also be possible to have more than one secondary stress, as in eng. *Àpalàchicóla* (Halle & Vergnaud 1987). It has been claimed that the domain of the realization of these alternating prominences is the *foot.*

The foot, a term inherited from the poetic tradition, indicates a constituent made of a stressed syllable and one or more unstressed syllables, representing an intermediate unit between the syllable and the phonological word (Liberman & Prince 1977, Hayes 1980, Selkirk 1980). Resorting to the

[8] See also chapters 3 and 4 on stress in Italian and German, respectively.

concept of foot allows to explain and make generalizations about many prosodic phenomena, such as stress placement, minimal word requirement, syllabic shortening and others (for an overview see Alber 2006, Kager 2007).

Typologically, what the maximum and minimum size of a foot and its components should be has been a matter of debate. However, the traditional view proposed by Hayes (1995) under Metrical Theory assumes that feet are binary in their standard form, i.e. made of two units, which might be either syllables or moras. A mora (indicated with μ) refers to a unit of weight which is used to represent the *heaviness* of a syllable,[9] i.e. its tendency to attract stress based on its segmental structure. More specifically, a syllable ending in a short vowel (CV[10]) is defined as a light syllable (indicated with L) and it is counted as monomoraic, while a syllable ending, for example, in one consonant (CVC) is defined as a heavy syllable (indicated with H) and it is counted as bimoraic.

The typology of binary feet proposed by Hayes, derived from the analysis of the prosodic patterns of the world's languages, assumes the existence of three types of feet: a syllabic trochee, a moraic trochee and an iamb, each having a degenerate form which may or may not be allowed in a language with the corresponding foot type. The trochee refers to a left-headed foot, i.e. a foot with stress on the left element, while the iamb refers to a right-headed foot, i.e. a foot with stress on the right element. The syllabic trochee is made of two syllables (indicated with σ) of any type (L or H), thus σ́σ. The moraic trochee consists of two moras, which can surface either as two light syllables (ĹL) or as a heavy syllable (H́), while the iamb is made of either three moras in the form of LH́ or two moras in the form H́ or LĹ. The complete foot typology is schematized in (4)

(4) Foot typology according to Hayes (1995).

	Licit forms			Degenerate forms
a) Syllabic trochee	(σ́ σ)			(σ́)
b) Moraic trochee	(σ́ σ)	(σ́)		(σ́)
	μ μ	μ μ		μ
	Ĺ L	H́		Ĺ
c) Iamb	(σ σ́)	(σ́)	(σ σ́)	(σ́)

[9] See section 2.4 on syllable weight for more details.

[10] When talking about the structure of syllables, C stands for consonants, V for vowel and G for glide.

μ μ μ   μ μ   μ μ   μ

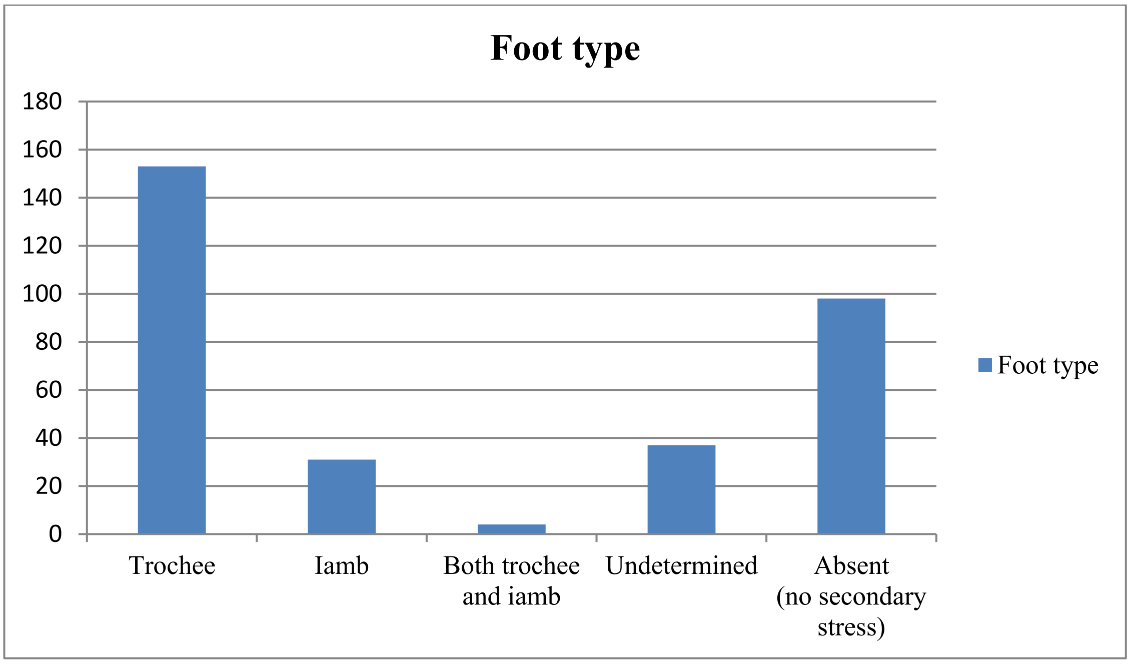
L H́   H́   L Ĺ   Ĺ

(adapted from Kager 2007)

As will be seen more specifically in sub-chapters 3.2 and 4.2, both Italian and German are usually analyzed as having trochaic feet.

With respect to the typological distribution of foot types, according to an analysis on the basis of the WALS database (https://wals.info/) by Goedemans and van der Hulst (2013c), it seems that the trochee is by far the most common type of foot, as can be seen in the following figure:[11]

Figure (1). Foot type typology (n = 323)



According to this analysis, 47% (153) of languages are reported as having trochees and 9% (31) have iambs, 1% (4) is analyzed as having both, while for the rest no clear foot type could be identified or no secondary stress was reported. The predominance of the trochaic foot structure also led some scholars to deny the existence of iambs altogether (van de Vijver 1998).

Another parameter which plays a role in the stress systems of the world's languages is extrametricality. The notion of extrametricality has been introduced in Metrical Theory because, given the above constrained typology of binary foot types, not all syllables in a word can be parsed

[11] It has to be noted, however, that this typological survey is based only on feet built on secondary stress, which, since they often occur reiteratively, allow a more straightforward categorization either as trochees or iambs than in the case of feet built on primary stress, whose categorization might be more difficult to determine.

into feet and also not all of them may contribute to determine the position to which stress is assigned (in languages that have such an algorithm to determine the position of stress). Hayes (1995) gives the example of Estonian, a language with extrametricality at the level of segments. In Estonian, CVC syllables attract stress, however, if the CVC syllable is in final position, it behaves like a CV syllable (which does not attract stress) suggesting that the final consonant should be counted as extrametrical, because it is invisible to the algorithm that determines stress assignment in Estonian. Another example of extrametricality can be seen in Latin. Latin is a language with predictable stress sensitive to syllable weight. However, only the weight of the penultimate syllables contributes to determine the position of stress and stress can only go either on the penult or antepenult. The final syllable is thus considered to be extrametrical in this language, since it neither influences the position of stress nor can it be parsed into a foot. As can be noted from the above examples, extrametricality is assumed to occur only at the word edge, either on the left or right margin. Typologically however, it seems that left-edge extrametricality is clearly more marked. In a survey on 80 languages made by Goedemans (2010) using the StressTyp databse (http://st2.ullet.net/), it appears that only 13 languages can be analyzed as having left-edge extrametricality. However, Goedemans notes that all these cases but one (Winnebago) are dubious, for example because the stress system itself is unclear in these languages. The other 67 languages are instead straightforwardly analyzed as having right-edge extrametricality. With respect to the unit which is extramtrical, it appears from the survey that in 66% of cases the extrametrical unit is the syllable, in 23% a segment, in 6% a foot, in 2% a mora and in 3% extrametricality is determined morphologically.

The final parameter characterizing the stress systems of the world's languages which will be analyzed here is whether a language allows a stress clash or not. A stress clash can occur when two (primary or secondary) stresses are found on two adjacent syllables, as in *thirtéen mén*,[12] (Lieberman & Prince 1977). Some languages tend to allow the presence of clashing stresses, while other languages tend to alternate stressed and unstressed syllables and might use different clash avoidance strategies. For example Nespor and Vogel (1989), based on their corpus of Italian, identify three main strategies for clash resolution: stress retraction, consisting in moving one of the clashing stresses to a different syllable (often the one bearing a secondary stress), beat deletion, consisting in deleting one of the clashing stresses and beat insertion, consisting in either lengthening the first clashing syllable or in inserting a pause between the two syllables (see Nespor and Vogel 1989 for a detailed discussion of these clash-avoidance strategies).

[12] Liberman and Prince (1977) also discuss cases of stress clashes in which the two stressed syllables are not immediately adjacent, as in *acromátic lénses*, which however stills create a stress clash according to the grid-based approach of Metrical Theory.

2.2.1 Primary Stress typology

With respect to the typology of primary stress, different stress systems are attested among the world's languages, depending on the position(s) that stress can have in the word and on the algorithm (if any) that determines stress assignment. The main distinction that can be drawn is between *bounded* and *unbounded* stress, both of which can be *predictable* or *unpredictable,* depending on the influence of syllable weight (Hayes 1995, Kager 2007).

Bounded stress refers to stress which is restricted to a specific stress window within the word, either to the left edge of the word, which comprises the first, second and third syllable or to the right edge of the word, which comprises the antepenult, penult and final syllable.

Predictable bounded stress refers to stress which is restricted to a specific stress window within the word and which is always predictable, either because it has a fixed position or because its position varies within the word in a predictable way on the basis of syllable weight.

Examples of languages with fixed stress on the left edge are Czech or Finnish, which both have fixed stress on the first syllable.[13] Examples of languages with fixed stress on the right edge are Polish and Turkish, which have fixed stress on the penultimate and final syllable respectively (van der Hulst *et al.* 1999). An example of a language where stress position varies within the word in a predictable way on the basis of syllable weight is Latin, in which stress is bound to the right edge of the word and it is assigned to the penult if this is closed by a consonant or if it ends in a long vowel, otherwise stress is assigned to the antepenult, as in *li.bér.tas* 'freedom' *vs á.nĭ.mus* 'soul'.[14]

Unpredictable bounded stress is found in languages where stress is restricted to a specific window but its position within this window cannot be determined in all cases. This is the case of both Italian and German, in which stress is bound to the right edge but its exact position is not fully predictable (see chapters 3 and 4).

Predictable unbounded stress can be found anywhere in the word but can be predicted on the basis of syllable weight. An example would be Classical Arabic, in which stress is assigned to the rightmost heavy syllable, if there is none stress is assigned to the leftmost syllable (Hayes 1995, Watson 2010).

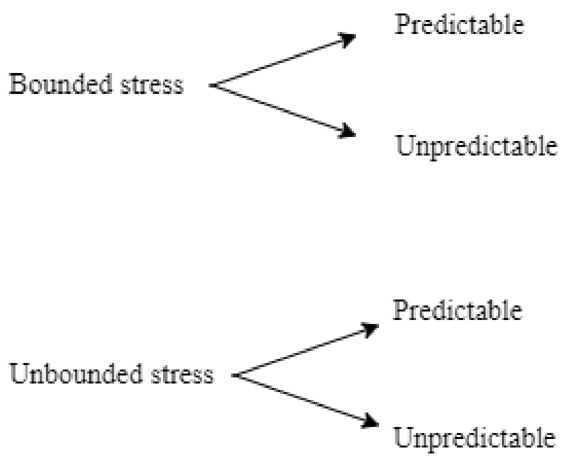
[13] According to van der Hulst's typological survey based on StressTyp, only one language (Winnebago) is attested having fixed stress on the third syllable (van der Hulst 2010).

[14] However, languages with predictable stress might still present exceptions, which might be regarded as lexical. For example, Polish, a language with regular penultimate stress, has still some words stressed on the antepenult or final, such as *uniwérsitet* 'university' (van der Hulst 1999: 16). Latin, in which stress is either on the penult or antepenult, also presents some words with final stress, which can be explained as the results of apocope from an original penultimate stress, such as *illíc* < *illíce* 'over there'.

Unpredictable unbounded stress, also called *lexical* stress, refers to stress which is not bound to a specific word edge, i.e. it can be found anywhere in the word, and it cannot be predicted by an algorithm. An example of a language with unpredictable stress is Russian.

In languages where stress is not entirely predictable, it is possible for stress to have a phonological function, allowing to distinguish between words which differ only in stress position, thus creating minimal pairs, such as English *íncrease* (noun) *vs incréase* (verb).

(5) Stress typology.

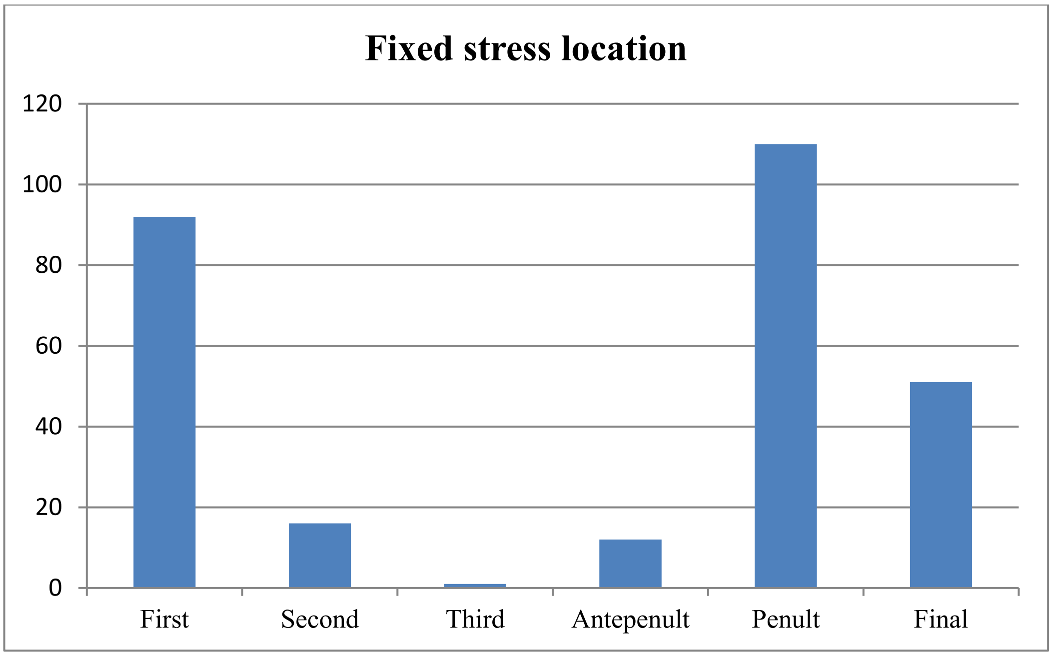


It must be noted that also morphology can play a role in determining the position of stress. Even in languages where stress is fixed to a certain position it might still be possible for an affix to be invisible to the stress rule of that language so that its presence causes stress to be found in a position different from the default one. Morphology can also play a major role in determining stress position in languages with unpredictable stress, in which, although stress cannot be predicted phonologically, some affixes might still be associated with specific stress patterns. Finally, it should also be noted that in some languages stress-assignment rules might also differ depending on word class. For example, in English it has been noted that in disyllabic nouns stress tends to fall on the first syllable, while in disyllabic verbs stress tends to fall on the last syllable, and this has also been confirmed experimentally (Guion *et al.* 2003). As will be seen in chapter (3), differences in stress-assignment depending on word class are also present in Italian, in which verbs allow a larger stress window than nouns, however the issue related to differences in stress-assignment depending on lexical class will not be dealt with extensively in this thesis, since the focus of the experimental part will be on nouns.

With respect to the typological distribution of primary stress, on the basis of a survey using the StressTyp database, comprising 500 languages, Goedemans (2010) reports that 44.5% (222) of the analyzed languages have non-fixed stress (including both quantity-sensitive and quantity-insensitive systems) while 55.5% (278) have fixed stress. Among the languages with non-fixed stress (n = 222), 54% are strictly sensitive to syllable weight (meaning syllables with a long vowel or a coda consonant), in 28% stress position is determined by factors others than vowel length and coda consonant,[15] and 18% have lexical stress.

With respect to languages with fixed stress, figure (2) shows the distribution according to a survey made by Goedemanas and van der Hulst (2013b) using WALS on 282 languages with fixed stress (out of a sample of 502 languages).

Figure (2). Typology of fixed stress location (n = 282).



As it is possible to see, the most represented fixed-stress pattern is the one which places stress on the penultimate syllable (39%), followed by stress on the initial syllable (32%) and stress on the final syllable (18%). Much rarer are languages with stress on the second syllable (5%) and on the antepenultimate syllable (4%), while only one language is reported as having fixed stress on the third syllable (Winnebago). Goedemans (2010) explains the predominance for initial and

[15] Goedemans includes in this category languages in which the position of stress is determined by vowel quality (e.g. vowel sonority) and also the case of tone languages in which stress position is purportedly determined by tone level, such in Northern Haida, in which stress is assumed to go on the last high-toned syllable, otherwise on the last syllable. (Goedemans & van der Hulst 2013).

penultimate stress as the consequence of the preference for trochaic feet among the world's languages (see figure (1) above).

2.3 Secondary stress

Secondary stress refers to a level of prominence intermediate between the one found on primary stressed syllables and the one found on unstressed syllables. This type of stress can be found especially on long polysyllabic words, such as in the word *lòcalizátion*, which might be pronounced with a secondary stress on the first syllable. While it is normally assumed that a word can have only one primary stress, long words in particular might have more than one secondary stress, as in Diyari *ká.na.wà.ra.ŋgùn.du* 'man' (pl. abl.) (Austin 1981, cited in Kager 2007).

As in the case of primary stress, secondary stress can be detected through some phonological phenomena. One example is vowel reduction, as in English, in which full vowels which do not bear primary stress are often assumed to bear a secondary stress, while all non-stressed vowel are reduced to a schwa.[16] Another piece of evidence for secondary stress comes from the domain of intonation. As for primary stress, also secondary stress has been reported to function as an anchor point for pitch accents in a sentence. Gussenhoven and Bruce (1999) state that a word like *Àberdéen* or a compound like *Ànglo-Sáxon* may have a pitch accent on the first syllable bearing a secondary stress besides on the syllable bearing a primary stress (6a). Furthermore, when a word like *Ànglo-Sáxon* is enclosed in a larger prosodic constituent, the word's pitch accent might be realized only on the syllable bearing secondary stress, as in (6b).[17]

(6)

a. Ànglo-Sáxon
H*L H*L

b. Ànglo-Sáxon Chrónicle
H*L H*L

(from Gussenhoven & Bruce 1999: 254)

[16] Some approaches assume that in English all the full vowels which do not bear primary stress bear secondary stress, while all unstressed vowels are reduced (Pater 2000). However, according to other approaches not all full vowels bear some stress.
[17] In this example H and L represent a high and low tone, respectively.

Further evidence in favor of the existence of secondary stress comes also from experiments using EEG, in which the position of stress is manipulated artificially and different ERPs responses are measured (Domahs *et al.* 2008, see sub-chapter 4.4 for further details).

When morphology does not play a role in the position of secondary stress, secondary stress placement in a word is determined by its directionality. Directionality of secondary stress refers to how a word is parsed into feet depending on the position of secondary stress. Two types of directionality are recognized: from left to right (or rightward) and from right to left (or leftward).

In a language with a left-to-right directionality, feet with secondary stress are built from the left edge of the word toward the right, as in Pintupi (Hansen & Hansen 1969, cited in Kager 2007):

(7) (σ́σ)(σ̀σ)σ ˈpu.lin̪.ˌka.la.tʲu ‘we (sat) on the hill’

In this example, primary stress is on the first syllable forming a disyllabic trochee. Another disyllabic trochee with a secondary stress is built from the left edge, leaving a syllable unparsed on the right.

In a language with a right-to-left directionality, feet with secondary stress are built from the right edge of the word toward the left, as in Warao (Osborns 1966, cited in Kager 2007):

(8) σ(σ̀σ)(σ́σ) ji.ˌwa.ra.ˈna.e ‘he finished it’

In this example, primary stress is on the penultimate syllable again forming a disyllabic trochee. Another disyllabic trochee with a secondary stress is built from the right, leaving a syllable unparsed on the left. As can be inferred from the above examples, the directionality of secondary stress can only be established looking at words with an odd number of syllables.

Typologically, it seems that the directionality of secondary stress correlates to a certain degree with the domain of primary stress assignment, although the correlation is not strong, as can be seen in table (1), based on a survey on 155 languages conducted by Goedemans (2010).

Table (1). Correlation between position of primary stress and directionality of secondary stress.

Domain of primary stress	Directionality of secondary stress	
	Left-to-right	Right-to-left
Left	63	12
Right	27	53

When main stress is assigned within the left edge of a word (75 languages of the analyzed sample), 84% of languages also have a directionality of secondary stress which parses into feet starting from the left, while 16% have an opposite directionality. In the case of languages where primary stress is assigned within the right edge of a word (80 languages of the analyzed sample), 66% have a directionality of secondary stress which parses into feet starting from the right, while 33% have an opposite directionality. In total, the cases of languages that present a mismatch between the location of primary stress and the directionality still amount to 39, i.e. 25% of the sample.

Another type of correlation that can be investigated is the one between directionality of secondary stress and foot type used in secondary stress assignment. Goedemans (2010), on the basis of a survey of 171 languages, reports the data represented in table (2).

Table (2). Correlation between foot type and directionality of secondary stress.

Foot type	Directionality of secondary stress	
	Left-to-right	Right-to-left
Trochaic	83	58
Iambic	22	8

From the data above it appears that the left-to-right directionality is the preferred one for both languages with trochaic and iambic feet. In the case of languages analyzed as having trochees (141), a slight majority, 58% (83), seems to have a directionality from left to right, while 41% (53) seem to have a directionality from right to left. In the case of languages analyzed as having iambs (30), the vast majority 73% (22) seems to have a directionality from left to right, while only 26% (8) seem to have a directionality from right to left.

The weak correlation between iambic feet and a right-to-left directionality has led some scholars to call into question the existence of such systems. For example, Alber (2005) proposes a different formal analysis in the framework of Optimality Theory (Prince & Smolensky 1993), according to which the directionality from left to right, which is attested for both languages with trochaic and iambic feet, is accounted for by the constraint All-Ft-L, which requires feet to be aligned to the left edge of the word, while the directionality from right to left in the trochaic system is not determined by the opposite constraints All-Ft-R, which is excluded from the analysis, but by the interaction of the constraints CLASH and LAPSE, which are responsible for an alternating rhythm (see also Hyde 2001, Kager's 2000, 2001).

The patterns of stress placement determined by either directionality can furthermore be disrupted in different ways. A phonological factor which can influence the position of secondary stress is syllable weight, as will be seen in more detail in the next section, so that, for instance, in a language with a directionality from left to right a second heavy syllable might attract secondary stress, as in the following example taken from Finnish (Carlson 1978, cited in Alber 1997b), in which primary stress is fixed on the first syllable (irrespective of its weight) and secondary stress falls on every odd syllable, except if there is a heavy syllable, in which case secondary stress falls on that syllable.

(9)	a. σ́σL̀LL̀LL	ó.pet.tè.le.mà.na.ni	‘as something I have been learning’
	b. σ́σLH̀L	ó.pet.ta.màs.sa	‘at teaching.iness’

As can be seen in (9b), the fourth heavy syllable attracts secondary stress and disrupts the directionality from left to right.

Another factor, in this case one related to morphology, which can disrupt the directionality of secondary stress is stress preservation (Alber 2009). Stress preservation refers to the fact that some morphologically complex words may retain a secondary stress on the same syllable which had a primary stress in the original word from which they derive, as in example (10) from Italian:

(10)	capàcitá	‘ability’	(LˌL)LY[18]	<	capáce	‘able’	L(YL)

In this example, the noun *capàcitá* is derived from the adjective *capáce* plus the suffix *-itá*, which forms abstract nouns from adjectives, and it may be pronounced with a secondary stress on the second syllable, i.e on the syllable which had primary stress in *capáce*. This happens in spite of the fact that Italian is usually thought to have a directionality from left to right (see chapter 3), which would imply a secondary stress on the first syllable as in *càpacitá*. As Alber and Arndt-Lappe (2020) note, a suffix might variably trigger stress preservation, depending on the type of base, as is the case of the German stress-bearing suffix *-ität* which triggers stress preservation in *Ùniversàlitä́t* from *universál*, but not in *Lòyalität* from *loyál*.

2.4 Syllable weight

Syllable weight refers to the property of a syllable to attract stress based on its segmental structure.

[18] Y represents a primary stressed syllable.

Sensitivity to syllable weight on stress assignment is one of the parameters that make up the typology of the stress systems of the world languages, meaning that syllable weight might be part of the prosodic systems of some languages while it will be missing in others. Furthermore, as will be shown below, some languages might show only a partial or variable sensitivity to syllable weight, so that in some cases syllable weight seems to be better analyzable as a gradient property rather than a discrete binary parameter.

Since the syllable is the relevant phonological domain for syllable weight, before discussing the role of syllable weight on stress assignment, first a brief overview of the concept of syllable will be provided.

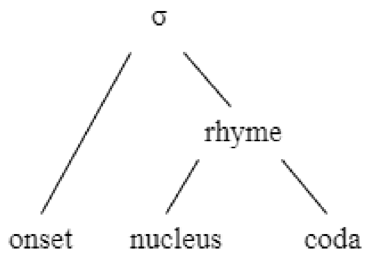
No consensus on a unanimous and comprehensive definition of the syllable has been reached, neither from a phonetic nor from a phonological point of view. However, broadly speaking, a syllable could be defined as a peak in sonority around a vocalic nucleus, optionally surrounded by some consonantal sounds, as in *in.ser.tion* [ɪn.sɜː.ɹ.ʃən], where the different syllables are divided by a dot. This definition, however, is still a partial one because it does not account for the different possibilities in syllabification, as in the word *busker*, which, in principle, could be syllabified as *bus.ker*, *bu.sker* or *busk.er* (Crystal 1985). In the prosodic hierarchy, the syllable represents a unit intermediate between the word and the single phonemes.

In spite of the issues surrounding its definition, the psychological reality of the syllable is well established and can be inferred from a variety of phenomena. One piece of evidence comes from slips of the tongue in spoken language involving swapping syllables or some of its segments, such as in Italian *dove stavolo dia?* instead of *dove diavolo sta?* ‘where the hell is it?’. Another example comes from argots which involve the manipulation of syllables, such as *Verlan* in French (Schmid 1999). In the phonological domain, syllable weight, i.e. the fact that the structure of the syllables determines the collocation of word stress, can also be considered as evidence for the syllable as an independent unit (see section 2.4).

Regarding the structure of the syllable, the traditional view considers the syllable as built around a nucleus, which is its only obligatory component, usually made of a vowel or a diphthong, but sometimes also made of a syllabic consonant.[19] The nucleus can be preceded by an onset, made of one or more consonants, and can be followed by a coda, made of one or more consonants. The nucleus and the coda in turn form another intermediate unit, the rhyme. The complete structure of the syllable is schematized in (3).

[19] Syllabic consonants are usually sonorants, as in the second syllable of English *bot.tle,* but obstruent syllabic consonants are also attested, e.g. in Imdlawn Tashlhiyt Berber (Zec 1995).

Figure (3). Maximal model of syllable structure.



Cross-linguistically, the segments around the nucleus, when present, tend to be organized according to a sonority scale, so that the most sonorous consonants (e.g. sonorants) tend to be found around the nucleus, which represents a peak in sonority, while the least sonorous (e.g. obstruents) tend to be found at the edges of the syllable. This tendency, which is usually referred to as 'Sonority Sequencing Principle', is based on the sonority hierarchy, which ranks classes of phonemes on the basis of their sonority level. An example of such a hierarchy is given in (11) (Blevins 2006), where the sonority is highest on the left and decreases towards the right.

(11) low vowels > mid vowels > high vowels > glides > liquids > nasal stops > fricatives > oral stops.

An example can be found in the monosyllabic word *grand* /grand/, in which the vocalic nucleus is surrounded by a liquid and a nasal, which in turn are surrounded by two voiced stops. However, many cases of syllables that do not follow the sonority hierarchy can still be found, as in the word *ax* /aks/, where a stop consonant in the coda is closer to the nucleus than a more sonorous sibilant fricative, thus apparently violating the sonority hierarchy. These cases are sometimes treated as instances of extrasyllabicity. For example, in the word above the /s/ would be considered extrasyllabic, meaning that it should thus not play a role in stress assignment. A different approach would consist in analyzing the consonant cluster as a single segment instead of made of two distinct consonants (Hall 2006).

With respect to the typology of syllable structures, it seems that the CV template is the most frequently attested one, since it is present in all languages, and it is thus designated as the least marked type of syllable. Another aspect that emerges from typological surveys is that, if a language allows an *n* numbers of segments in the onset or in the coda, then it also allows a *n* -1 numbers of segments in the same positions, e.g. if CVCC is allowed then also CVC must be allowed (Blevins 1996).

The different syllabic structures that are present in a language give rise to different types of syllable weight, which might play a role in stress assignment. The next paragraph will be dedicated in more detail to the concept of syllable weight.

As anticipated above, syllable weight refers to the property of a syllable to attract stress based on its segmental structure. As will be shown below, syllable weight can influence not only the collocation of primary stress, but also of secondary stress.

Among the world's languages, syllable weight can manifest itself in different ways, which could be summarized through the following parameters:

(12) a. Type of the heavy syllable(s)
b. Position of the heavy syllable(s) in the word
c. Number of contrasts for weight (two-way or three-way contrast)
d. Degree of sensitivity of stress to the heavy syllable(s) (total or partial)

One example of language sensitive to syllable weight is Latin. In this language, stress is predictable through an algorithm based on syllable weight, according to which, if the penultimate syllable in a word is closed by a consonant (CVC) or ends in a long vowel (CVV), stress goes on that syllable, which would thus be called a *heavy* syllable (H). Otherwise, if the penultimate syllable ends in a short vowel (V̌), stress falls on the antepenultimate syllable, which would be then called a light syllable (L). The algorithm for stress assignment in Latin is schematized in (13) and exemplified in (14).

(13) If P is heavy (= ends in a consonant or long vowel) stress falls on P, else falls on A.

(14)	a. *li.bér.tas*	'freedom'	X.CVC.X	P = heavy
	b. *vir.tū́.tem*	'virtue.acc'	X.CVV.X	P = heavy
	c. *hú.mĭ.lis*	'humble'	X.CV.X	P = light

As can be seen in (14a) and (14b), since the penult is heavy (either closed by a consonant or with a long vowel), stress falls on the penult, while in (14c), since the penult is light (ending in a short vowel) stress falls on the antepenult. It can be thus concluded that Latin has a two-way contrast for weight (heavy *vs* light syllables) and that only the penultimate syllable is sensitive to syllable weight and it is thus relevant for stress assignment. Furthermore the algorithm applies in all cases irrespective of other factors such as morphology, indicating that Latin is fully sensitive to syllable weight.

According to Moraic Theory (Hyman 1985, Hayes 1989), heavy syllables are usually analyzed as made up of moras (μ), i.e. units of weight, which are linked to the syllable segments, so that a heavy CVC syllable is made of two moras, as opposed to a light CV syllable which is made of only one mora. Heavy syllables can be made of up to three moras, so that in some languages a three-way distinction of weight can be established, as represented in (15) (see also further below):

```
(15)    CVVC > CVC > CV
          | | |    | |    |
          μ μ μ    μ μ    μ
```

In this example, a superheavy syllable, i.e. a syllable made of three moras, is heavier than a heavy syllable, which is in turn heavier than a light syllable.

Typologically, different factors have been observed to contribute to syllable weight. In (16) a list of the main factors is provided, where each factors is associated with its respective constituent within the syllable:

(16)	a. consonant(s) of the coda	} coda
	b. vowel length	} nucleus
	c. diphthong	
	d. vowel sonority	
	f. consonant(s) of the onset	} onset
	g. high tone	

The first parameter, as seen in the example with Latin *li.bér.tas*, refers to that fact that, in some languages, a syllable closed by a consonant (CVC) attracts stress. Within this type of syllable weight, some languages also distinguish between consonants that contribute to syllable weight and consonants that do not. For example, Lithuanian is reported to be a language in which a syllable with a long vowel, a diphthong or ending in a sonorant consonant (CVR) counts as heavy, while a syllable ending in an obstruent (CVO) counts as light[20] (Zec 1995, Dogil & Möhler 1998).

Another differentiation among the weight systems where closed syllables count as heavy concerns the number of consonants that make up the coda of the heavy syllables. As anticipated

[20] Lithuanian is usually described as having a pitch accent instead of stress, so the algorithm in this case applies to a pitch accent (Dogil & Möhler 1998).

when introducing Moraic Theory, some languages differentiate between the weight of codas made of one consonants and codas made of more than one consonant, the latter of which constitute thus *superheavy* syllables, so that the syllable with most segments in the coda counts as heavier than the one with less segments, giving rise to a three-way system of weight. Hindi is an example of a language with such a system. Besides heavy syllables with a long vowel (CVV) or closed by a consonant (CVC), Hindi also possesses superheavy syllables with a long vowel plus a consonant (CVVC) and with a short vowel plus two consonants (CVCC). When a heavy syllable and a superheavy syllable coexist in the same word, stress goes on the rightmost non-final superheavy, while, if no superheavy is present, stress goes on the rightmost non-final heavy syllable, as shown in (17) (Hayes 1995):

(17)	a. ʃóox.ja.baa.nii	'talkative'	CV́VC.CV.CVV.CVV
	b. kaa.ríi.ga.rii	'craftsmanshift'	CVV.CV́V.CV.CVV

Turning now to parameter b. of the list in (16), vowel length refers to a parameter found in languages where syllables with long vowels (CVV) count as heavy, as seen in some previous examples, such as Latin and Hindi. One instance of a language where only syllables with long vowels are heavy is Khalkha Mongolian, in which stress falls on the final heavy syllables (CVV), if the final is the only CVV syllable in the word. However, if there are more than one CVV syllables in the word, stress falls on the rightmost non-final heavy. If there are only light syllables, i.e. both CV and CVC, stress goes on the first syllable (Walker 1995).

Heavy syllables with long vowels occur in languages where vowel length is phonemic, as in all the cases cited above. However, it is less clear whether syllables with long vowels might count as heavy also in languages where the distinction between long and short vowels in not phonemic. Zec (1995) on the basis of the typological implication based on the sonority of syllabic segments (see below) proposes that it should be the case that languages with non-phonemic vowel length might also have heavy syllables with long vowels, however she does not explicitly cite any example of a language of this type. One possible example could be English, which possesses a distinction between short and long vowels. This kind of vowels contributes to minimal pairs, but since they also differ clearly in quality (lax *vs* tense) the phonemic distinction is not usually regarded as one based on length but rather on tenseness, as in /bɪd/ (lax, short) *vs* /bi:d/ (tense, long). In spite of this, English is usually analyzed as dependent on syllable weight, where both closed syllables and syllables with long vowel count as heavy (Pater 1995). It has to be noted, however, that even if long vowel count as heavy in English, the influence of syllable weight in this language differs from the one found in a languages like Latin, since in the latter it is categorical, i.e. it happens in all cases with no exceptions, while in the former it represents only a tendency, as suggested by the presence of words with unstressed potentially long/tense vowels, such as *create* /kriˈeɪt/.

With respect to the two parameters discussed so far (consonant of the coda and vowel length), on the basis on the attested typology for these types of weight, Zec (1995), following Trubetzkoy's insight, proposes that they could be arranged in a hierarchy based on the sonority of the segments that make up the syllable. More specifically, Zec shows that languages are constrained in the set of segments that are moraic and which thus contribute to the weight of syllables, according to the following scheme, where the relevant parameters are vowel length, a sonorant coda and an obstruent coda:

(18) Set of moraic segments by language type:
a. only vowels (e.g. Khalkha Mongolian)
b. vowels and sonorants (e.g. Lithuanian)
c. vowels, sonorants and obstruents (e.g. English)

On the basis of (18), it is possible to derive an implicational typology, according to which, if in a language a syllable closed by a sonorant (CVR) counts as heavy, also a syllable with a long vowel (CVV) counts as heavy (b.), and, if in a language a syllable closed by an obstruent (CVO) counts as heavy, also both a syllable closed by a sonorant (CVR) and a syllable with a long vowel (CVV) count as heavy. This generalization holds only for languages that have the above mentioned segments in their phonological system. For instance, if a language does not possess a distinction between long and short vowels it might still have heavy CVC syllables without having heavy CVV syllables.

Diphthongs are another category of sounds which can attract stress. For example, one experimental study in Spanish showed that falling and rising diphthongs on a penultimate syllable count as heavy and that falling diphthongs are (gradiently) heavier than rising diphthongs (Shelton 2007). One question that arises in the case of the weight of diphthongs is how they should pattern in their stress-attracting behavior with respect to long vowels and closed rhymes, and, accordingly, where they should be placed in Zec's hierarchy. Taking as a reference the concept of sonority, one hypothesis would be to assume that diphthongs, since they are made of a vowel plus a glide, represent an intermediate unit less sonorous than a long vowel and more sonorous than a rhyme closed by a consonant. However, as was found in Spanish, there might be a further difference between falling diphthongs, which could be analyzed as made of a vowel plus a very sonorous coda, and rising diphthongs, in which the initial glide could also be analyzed as an onset element, thus probably playing a lesser role in attracting stress.

The next parameter contributing to syllable weight which will be analyzed is vowel sonority. Vowel sonority refers to the intrinsic sonority that single vowels possess. Kenstowicz (1996) shows that some languages use the sonority of the vowel in the syllable as a cue for stress, according to the following scale:

(19) /a/ > /e/, /o/ > /i/, /u/ > /ə/

As can be seen in (19), low vowels count as heavier than mid vowels, which in turn count as heavier than high vowels, which are heavier than a reduced central vowel. One language sensitive to vowel sonority for stress assignment cited by Kenstowicz would be Kabon, as can be seen from the following examples:

(20)	/a/ > /i/	ki.á	‘tree species’
	/o/ > /u/	mó.u	‘thus’
	/o/ > /i/	si.óg	‘bird species’

From the three examples in (20) it is possible to see that in Kabon stress is always placed on the most sonorous vowel which is present in the word.

The last main type of weight which will be surveyed here is the one represented by the syllable onset. In the literature the onset has often been regarded as a syllabic constituent which plays no role in stress assignment, which is thus often assumed to be determined entirely by the rhyme. However, more and more evidence seems to suggest that the onset can have at least a partial influence on syllable weight. One of the first piece of evidence which have been brought forward as an example of language in which the onset plays a role in stress assignment is Pirahã (Everett & Everett 1984). In this language, an onset made of a voiced consonant (GV) is heavier than on onset made of voiceless consonant (CV), giving rise to the following scale of weight:

(21) GVV > CVV > VV > GV > CV

Sensitivity to onset for stress assignment has also been found in some languages as more of a tendency which allows exceptions rather than a categorical rule. For example, Ryan (2014), in a corpus analysis on the English lexicon, found that the complexity of the onset correlated with the probability of a syllable to receive stress in both initial and medial position in disyllabic and trisyllabic items. Opposite to the case of Pirahã, he found that in English voiceless onsets tend to attract more than voiced onsets. The results of the corpus analysis were also confirmed by a series of perceptual and nonce word experiments. A strong correlation between stress and onset complexity was also found by Ryan in the Russian lexicon.

For the sake of completeness, in the list of syllable weight typology in (16) also point (g) has been added, representing languages with a mixed system in which stress is attracted by syllables having a specific tone or pitch-accent, although these cases are not widely reported in the literature on syllable weight, so they will not be discussed here. This type of weight has been cited for example by Hayes (1995) as occurring in a few languages, such as Serbo-Croatian, Lithuanian and Golin. For instance, in Golin (Bunn and Bunn 1970, cited in Hayes 1995) stress is said to fall on the last syllable which bear a high tone, while in words with only low tones stress falls on the final syllable.[21]

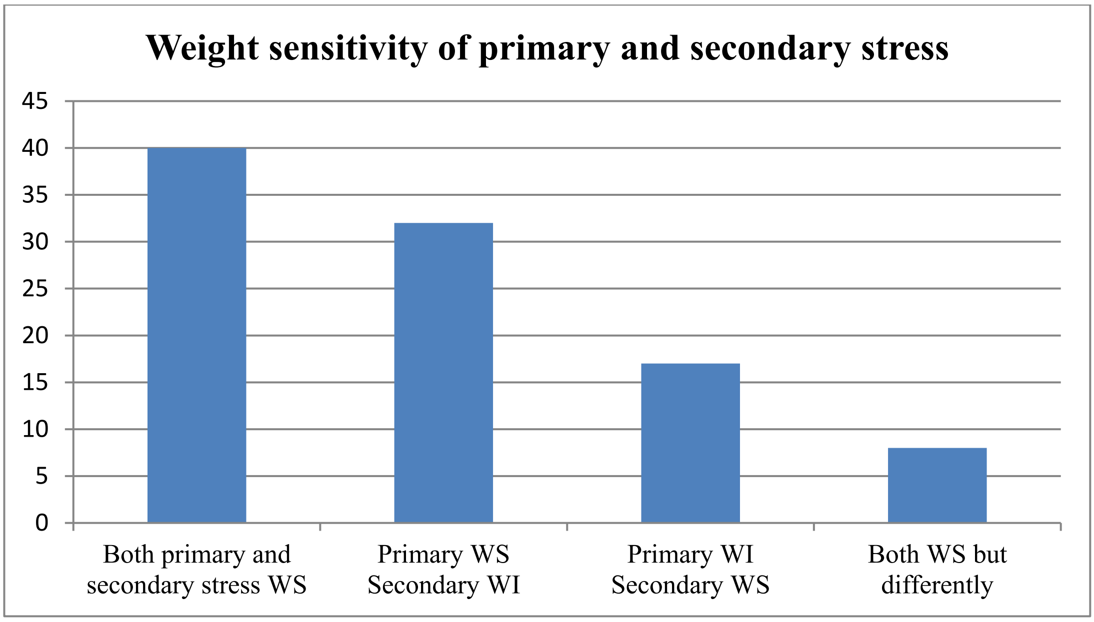
All the cases discussed so far represent instances of influence of syllable weight on primary stress. However, the influence of syllable weight on secondary stress is also well attested among the world's languages. The parameters that can influence secondary stress assignment seem to be the same that can influence primary stress, or at least a subset thereof, as I am not aware of any study which explicitly reports cases of secondary stress placement influenced by vowel sonority or tone, but this might be only a due to the fact that secondary stress in languages which might have this type of syllable weight has not been thoroughly studied yet. In any case, as shown in figure (4) further below, it has to be noted that neither weight sensitivity for primary stress implies weight sensitivity of secondary stress (and vice versa) nor both levels of stress have to be necessarily sensitive to the same types of syllable structures or to the same degree.

One example of weight sensitivity with respect to secondary stress is found in Finnish. In Finnish, primary stress is fixed on the first syllable and secondary stress falls on every odd-numbered syllable counting from the left, however, if a heavy syllable of the type CVC or CVV is present secondary stress falls on that syllable (Alber 1997b). In English, a distressing rule involving secondary stress has been attested (Nanni, 1977 cited in Davis 1988) in words ending with the suffix -*ative.* These type of words usually have a secondary stress on the first syllable of the suffix, as in *invéstigàtive.* However, secondary stress is lacking in words like *nóminative.* According to Nanni, this is because in English a destressing rule deleting secondary applies in the case of syllables with a sonorant onset.

[21] Gordon (2004) reports also of tonal languages in which tones types (e.g. level *vs* contour tones) are restricted to specific heavy syllables, as in Kiowa, where contour tones occur only on CVV and CVR syllables while level tones occur in any kind of syllable. Syllable weight in relation to tonal language will not be dealt with in this thesis.

Regarding the typology of weight sensitivity with respect to both primary and secondary stress, Goedemans (2010), on the basis of a survey on 97 languages, reports the following data, reported in figure (4):

Figure (4). Correlation between weight-sensitivity of primary and secondary stress. WS = weight sensitive, WI = weight insensitive.



As can be seen from the figure above, in the relative majority of the surveyed languages both primary and secondary stress are weight-sensitive, i.e. 41% (40). In 33% (32) of languages primary stress is weight-sensitive and secondary stress is weight-insensitive, in 18% (17) primary stress is weight-insensitive and secondary stress is weight-sensitive and in 8% (8) both stresses are weight-sensitive but in different ways. Overall, it is possible to notice that when primary stress is sensitive to syllable weight, i.e. in 80 of the surveyed languages, in a slight majority of cases, 60%, also secondary stress is sensitive to syllable weight, while in 40% of cases it is not.

2.5 Summary

This chapter has provided an overview on the main concepts related to the prosodic systems of the world's languages, with a particular focus on primary and secondary stress and on syllable weight.

In the first part of the chapter, it has been seen how prosody can manifest itself in different ways, such as through stress, pitch-accent and tone and in different prosodic domains, such as in the lexical or post-lexical domain.

The second part has focused more specifically on stress and its properties and typology. The concept of foot and its universal inventory, made of trochees and iambs, has been presented. Then the main patterns of primary stress assignment has been discussed. Finally the concept of secondary stress and its properties, such as directionality has been introduced.

The third part has provided an overview on the definition of the syllable and on the phenomenon of syllable weight, discussing the different ways in which it can manifest itself.

Based on what has been discussed so far, in (3) a summary table with the main parameters which make up the prosodic system of a language is provided.

Table (3). Summary table of stress parameters.

Foot	Type	Moraic trochee / Syllabic trochee / Iamb
	Degenerate foot	Yes / No
Extrametricality		Yes / No
Stress clash		Yes / No
Primary stress (PS)		Bounded (predictable/unpredictable) / Unbounded (predictable/unpredictable)
Weight sensitivity of PS	Type	Coda / Diphthong / Vowel length / Vowel sonority / Onset / Tone
	Degree	Total / Partial
Secondary stress (SS)		Yes / No
Directionality of SS		Left-to-right / Right-to-left
Weight sensitivity of SS	Type	Coda / Diphthong / Vowel length / Vowel sonority / Onset / Tone
	Degree	Total / Partial

The next two chapters will be dedicated to analyze more in detail the topic of interest of this work, i.e. the stress systems of Italian and German, and to analyze how the above mentioned parameters apply to these language, with a specific focus on syllable weight with respect to both primary and secondary stress.

3 Stress and syllable weight in Italian

3.1 The syllable in Italian

Before discussing the role of syllable weight in the Italian stress system, a brief overview of the structure of the syllable in Italian is provided (Krämer 2009, Schmid 1999).

The classical structure of the syllable in Italian includes an optional onset, which can be made of up to three consonants, a nucleus, consisting in a vowel or a diphthong, and an optional coda, made of only one consonant, giving rise to a maximal syllable structure of the type (CCC)(G)V(G)(C),[22] where the only obligatory component is the vocalic nucleus.

With respect to the onset, if it is made of only one segment, the segment can be any consonant of the phoneme inventory of Italian. If the onset is made of two segments, they can be either a stop or fricative followed by a liquid (either /l/ or /r/), e.g. *pra.to* 'lawn', or an /s/ plus any consonant, except affricates, e.g. *spa.da* 'sword'. Some exceptions are found in the 'learned' vocabulary, i.e. words of Greek origin or word of Latin origin which were borrowed in the language and did not undergo the typical sound changes characterizing the historical development from Latin to Italian, such as *pte.ro.dat.ti.lo* 'pterodactyl'. If the onset contains three segments, these must be an /s/ plus an obstruent plus a liquid (either /l/ or /r/), e.g. *strap.pa.re* 'to tear'. Since the first segment is always /s/ and since it violates the Sonority Sequence Principle, it is usually assumed to be extrasyllabic (Alber 2007).

With respect to the nucleus, it can be made of a single vowel V or a diphthong, either rising GV or falling VG. Italian does not have a phonemic distinction between long and short vowels, as it was the case in Latin, however vowels in open syllables are usually longer than vowels in closed syllables, especially when stressed in penultimate position (see section 3.2).

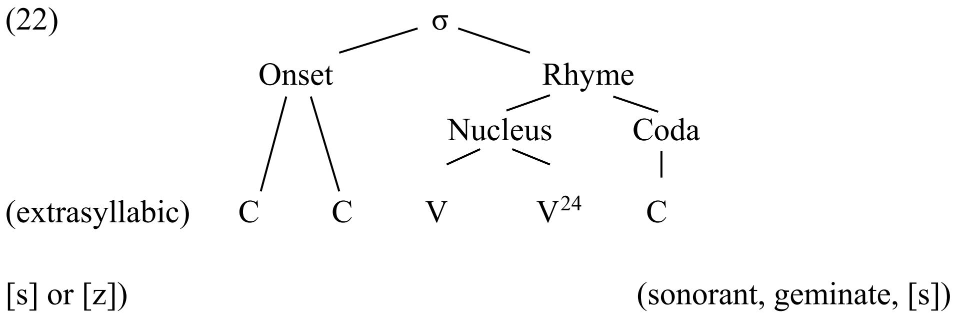
With respect to diphthongs, according to some approaches (Krämer 2009), rising diphthongs should be analyzed as a glide plus a vocalic nucleus, where the glide is considered part of a complex onset. The rationale of this argument is that, while in Italian falling diphthongs almost never occur in closed syllables, rising diphthongs do, e.g. *pianta* /pjan.ta/ 'plant' and therefore, if the glide plus vowel were both to be considered part of the nucleus, this type of syllable would exceed the maximum size of a foot in Italian, which in this analysis is assumed to be bimoraic (see below). Besides diphthongs, also some triphthongs are reported, such as *quieto* /kwjɛto/ 'calm', although only very few cases are attested.

[22] G stands for 'glide'.

With respect to the coda, it can be made of any consonant when it forms the first part of a geminate, e.g. *pat.to* ‘pact’. Alternatively, it can be made of a sonorant (/l/, /r/, /n/, /m/) or an /s/[23] when it is followed by a different consonant in the next syllable, as in *len.to* ‘slow’ and *bos.co* ‘forest’ respectively. In the native vocabulary, closed syllables are found only word-internally and they cannot have more than one coda consonant, which means that there are no superheavy syllables of the CVCC type, although there are syllables made of a rising diphthong plus a consonant, CGVC, as in *nien.te* ‘nothing’, which could potentially count as superheavy, assuming that the glide is counted as part of the nucleus. However, the above generalizations regarding the maximal syllable size and the type of codas have some exceptions, found especially in loanwords, e.g. *cac.tus* (stop coda not part of a geminate as well as word final coda) and *sport* (complex coda).

The overall structure of the syllable in Italian is summarized in (22) (Alber 2007, Krämer 2009):

(22)



(adapted from Alber 2007)

3.2 The foot in Italian

The Italian foot has been traditionally analyzed as trochaic at some level of analysis (Alber 2008), meaning that it is assumed to be binary and left-headed, although some proposals assuming ternary feet have also been advanced, which would imply excluding extrametricality (cf. Nespor 1993, Bafile 1999).

Within the trochaic analysis, the major consensus in the literature is that Italian builds moraic trochees (i.e. having stress on the first mora) rather than syllabic trochees (i.e. having stress on the first syllable) (D’Imperio & Rosenthall 1999, Krämer 2009, Morén 1999). For instance, D’Imperio

[23] Although in the orthographic practice <s> followed by one or more consonants is usually syllabified with the following syllable, as in *bo-sco*. There is however evidence that in Italian the phoneme /s/ should be counted as the coda of the previous syllable, as in *bos.co*, as suggested by the fact that the vowel in /bos/ is short like all vowels in closed syllables in Italian (Nespor 1993).

[24] Here, two Vs represent either a rising or falling diphthong.

and Rosenthall (1999) argue for an analysis of the Italian foot as a moraic trochee based on the fact that in LLL words, the vowel in a penultimate stressed syllable is considerably longer than the one in an antepenultimate stressed syllable, suggesting that in LĹL phonological lengthening takes place due to the fact that the penultimate syllable is assigned two moras, thus building a foot on its own, L(Ĺ:)L, while in ĹLL the antepenult undergoes only a slight phonetic lengthening due to the presence of stress, indicating that it receives only one mora and that it builds a bimoraic foot together with the unstressed penult, (ĹL)L. In this analysis, the last syllable, when unstressed, is thus considered to be extrametrical.

Krämer (2009) agrees with D'Imperio and Rosenthall's analysis, in support of which he further adds his own vowel measurements of ĹHL words (words like *pó.liz.za,* see below) in which he claims that the stressed vowel in the antepenult has a similar duration to the stressed vowel in LĹL, being both longer than the stressed vowel in ĹLL, suggesting that also ĹHL builds its own bimoraic foot on the first syllable (L:)HL, avoiding the formation of a trimoraic *(LH)L foot.

While the bimoraic trochee can be considered the standard foot form in Italian, also degenerate feet seem to be possible, which in this case would be feet made of only one mora. For instance, Alber (2008) points out the presence of many one-syllable words in Italian, such as *blu* 'blue' and some cases of final stress, as in *cittá*[25] 'city', which under a trochaic analysis would be parsed as *cit(tá)*, H(Ĺ), with a final degenerate trochee. She notes that the productivity of degenerate feet is also attested in truncation processes, such as in the personal name *Cri* < *Cristina.*

3.3 Primary stress and syllable weight in Italian

Italian primary stress can be described as variable, since it is not fixed on a specific syllable, however, it can be considered semi-predictable, because, even if it is not fixed, it is still bound to a specific stress window, namely the last three syllable of a word. However, one exception to this rule is found in some verbs, which can have stress on the fourth-to-last syllable in the 3rd person plural such as *á.bi.ta.no* 'they inhabit/live', or more generally when a verb has two enclitic pronouns attached to it, as in *mét.ti-ce-ne* 'put-some of it-in there'. Some examples are shown in (23).

(23)	a. final stress:	cit.tá	'city'
	b. penultimate stress:	lo.cá.le	'local'
	c. antepenultimate stress	fá.ci.le	'easy'

[25] Final stress in Italian is graphically marked with a diacritic symbol, usually a grave accent. For this reason, in standard Italian orthography this word would be written <città>.

d. pre-antepenultimate stress á.bi.ta.no ‘they inhabit/live’

With respect to its distribution, primary stress in Italian falls most frequently on the penultimate syllable (about 70-80% of the times), which is thus considered the default position for stress in Italian, about 20% of the times on the antepenult and about 2% on the final (Borelli 2002 cited in Krämer 2009, see also my own corpus analysis in chapter 9).

The fact that the default position of stress is on the penult is also suggested by the results of some experiments investigating the effect of word neighborhood on stress. The neighborhood effect refers to the fact that, when assigning stress to nonce words, speakers tend to collocate stress on the basis of the number of real words that share the same ending as the nonce words. For instance, if a nonce word has an ending which in the real lexicon is associated mostly with antepenultimate stress (e.g. *-olo* as in *távolo* ‘table’), the nonce word will also tend to be stressed mostly on the antepenult. On this basis, Colombo *et al.* (2014) tested how nonce words with a strong penultimate neighborhood (i.e. triggering penultimate stress) and nonce words with a strong antepenultimate neighborhood (i.e. triggering antepenultimate stress) prime words with ambivalent neighborhood.[26] The authors found that, when a nonce word with ambivalent neighborhood was primed by a nonce word triggering penultimate, stress stress fell on the penult 76% of the times, but when a nonce word with ambivalent neighborhood was primed by a nonce word triggering antepenultimate stress, stress fell on the antepenult only 54% of the times, suggesting that there is a bias for penultimate stress in Italian. This bias was also confirmed by an experiment using eye-tracking (Sulpizio & McQueen 2012), in which participants had to recognize words with the same first two syllables and with either antepenultimate or penultimate stress (e.g. *cánapa vs canále*). The results indicated that participants used acoustic cues related to stress only to detect words with antepenultimate stress, while words with penultimate stress were identified simply on the basis of the expectation of stress on the penult.

Concerning the influence of syllable weight on primary stress in Italian, looking at the Italian lexicon, it is possible to see that if a penultimate syllable is closed by a consonant (CVC) it always attracts stress, as in *ca.vál.lo* ‘horse’[27], suggesting that Italian is weight-sensitive at least in the case of a closed penult. From a diachronic perspective, this can be explained by the fact that already in Latin a closed penult was always stressed, on the basis of the Latin stress algorithm, which says that

[26] This study investigated also other conditions, but this is the one relevant to understand default stress in Italian.

[27] There are only a few exceptions to this rule, for example *pó.liz.za* ‘insurance policy’ or *mán.dor.la* ‘almond’. A specific category of words that shows this exceptional pattern, which is not usually cited in the literature, consists in the infinitive form of 2nd conjugation reflexive verbs with stress on the antepenult, such as *ac.cór.ger.si* ‘to realize’ and in the infinitive form of the 2nd conjugation verbs with stress on the antepenult plus an enclitic pronoun, e.g. *prén.der.lo* ‘to take it’, from *prén.de.re* ‘to take’ plus *-lo* ‘it’. Another category of exceptions to this rule is represented by some words with final stress, such *ve.ner.dí* ‘Friday’ or *cit.tá* ‘city’.

if a penult ends in a consonant or in a long vowel stress goes on that syllable, otherwise stress goes on the antepenult. Looking at the antepenult, it is possible to see that, even if it has a CVC structure, it is not necessarily stressed, since both words like *zúc.che.ro* CV́C.CV.CV 'sugar' and *can.zó.ne* CVC.CV́.CV 'song' are attested. Concerning the final syllable, which is rarely closed in Italian (mostly in loanwords), Krämer (2009), on the basis of acronyms of companies, notes that a closed final syllable does not usually receive stress, as in ÉNEL (*Ente Nazionale per l'energia ELettrica*) or ÁNAS (*Azienda Nazionale autonoma delle AutoStrade*). However, it should be noted that in Italian many English loanwords with a final syllable ending in one or more consonants or a diphthong plus a consonant are pronounced with final stress, even if the penult is closed and even if in English primary stress was originally on the left side of the word,[28] as in (24):

(24)	a. previéw	CCV.CGVC
	b. emáil	V.CVGC
	c. weekénd	CV.CVCC
	d. downlóad	CVGC.CVC
	e. copyríght	CV.CV.CVGC

Since there are however many counterexamples, such as *séquel*, *éxport*, *fáshion*, a corpus analysis on these types of loanwords might more accurately reveal whether the weight of the final syllable plays at least a partial role in Italian.

In order to investigate the role of the consonant of the coda in Italian, Krämer (2009) ran a small nonce word experiment in which 12 native Italian speakers (mostly from northern Italy) were asked to read 24 nonce words with different length and syllable structures, inserted in a carrier sentence. The investigated structures were the following:

(25)	2-syllable:	a. LL
		b. HL
	3-syllable:	c. LLL
		d. LHL
		e. HLL
		f. HHL
	4-syllable:	g. LLLL

[28] However, an alterntive reason why in the Italian pronunciation of English loanwords stress is collocated on the right margin might also be due to the fact that many of these words might be analyzed as compounds (as they originally were) and in Italian compounds primary stress goes on the constituent on the right.

These items allowed to investigate the influence of syllable weight, in this case through the consonant of the coda, on stress in the antepenult and penult, but not in the final syllable, since, in Italian orthography, a final syllable is stressed only if the vowel is graphically marked with an acute or grave accent.

The results of this experiment indicate that in the disyllabic items, stress is systematically placed on the first syllable (100%), as expected.

In the case of trisyllabic items, if the word is made only of light syllables (LLL) stress is placed almost equally on the antepenult (44.9%) and on the penult (55.1%), suggesting no specific default position. If the word has a heavy antepenult, as in HLL, stress goes mostly on the penult (71%) and only 29% on the antepenult, suggesting not only that a closed antepenult does not play a role in stress assignment, but also hinting to a stress-repelling effect, since the percentage of a stressed heavy antepenult is even less than a stressed light antepenult. If the word has a closed penult, stress goes systematically (100%) on that syllable, irrespective of whether the antepenult is light (LHL) or heavy (HHL), confirming that a closed penult always attracts stress.

In the case of quadrisyllabic items with only light syllables LLLL, stress goes overwhelmingly on the penult (91.7%), thus showing a different pattern than in the LLL type.

Krämer accounts for the variation found in the LLL, HLL and somewhat less in the LLLL types through an OT analysis couched within Stratified Grammar (Anttila 2003), according to which grammar is organized in strata of unranked constraints which assume a random ranking at each evaluation, thus allowing to account for the variation which is attested in the empirical data. For instance, to explain the variation found in the HLL type (71% of stress on the penult and 29% on the antepenult) the author postulates the highly ranked constraints NonFinal >> Foot= μμ and then the four unranked constraints Parse-σ, AllFtR, Edgemost-R and WSP. Among all the possible rankings of these four constraints, 8 favor stress on the antepenult and 16 on the penult, close to the distribution found in the nonce word experiment.

Overall, Krämer's results confirm the expectations that a closed penult always attract stress, while suggesting that the weight of the antepenult does not play a role in stress assignment, although these results should be taken with caution because of the small number of items and participants.

Another piece of evidence regarding the role of syllable weight comes from a set of experiments run by Kaschny (2011). Because the penult seems to be the only syllable sensitive to syllable weight, the author assumes that in Italian stress is assigned on the basis of an algorithm, according to which stress goes on the penult if this is closed by a consonant, otherwise stress goes on the antepenult, which she labels *Silbenstruktur-Hypothese.* All other cases of stress should be regarded as lexically specified, i.e. stress on an open penult (e.g. *fe.lí.ce*) final stress (e.g. *vir.tú*) and stress on the antepenult when the penult is closed (e.g. *mán.dor.la*). The *Silbenstruktur-Hypothese* is formulated in contrast with the hypothesis that stress is place by default on the penult, and all other cases are counted as lexical (*Penultima-Hypothese*).

If one assumes the *Silbenstruktur-Hypothese* as true, according to a corpus analysis run by Kaschny on about 7120 three-syllable words from the *Lemmi di Base* ('basic vocabulary') of the *Dizionario Italiano Sabatini Coletti* (1997) 58.2% of the words follow the rule-based accentuation, while 41.8% of words have lexical stress. The author goes further by also adding the role of morphology in the analysis, distinguishing words with suffixes which determine stress position (i.e. associated either with stress on the antepenult, penult or final) and words without suffixes (where stress is thus unpredictable in the limits of the Silbenstruktur-Hypothese),[29] On the basis of these data she compares the degree of stress predictability of the *Silbenstruktur-Hypothese* and that of the *Penultima-Hypothese*. She calculates that, assuming the former, stress is predictable in 96.0% of the words, while assuming the latter, stress is predictable in only 88.3% of the words, so she concludes that the *Silbenstruktur-Hypothese* should be preferred. However, taking into consideration only the role of phonology, i.e. of syllable structure, in determining the position of stress in Italian, it is clear that the hypothesis that stress is placed by default on the penult (both when the open is light and when it is closed) makes stress predictable in 74.3% of the words (using Kaschny's data, but see also my own corpus analysis in chapter 9) against only 58.2% of the *Silbenstruktur-Hypothese.*

The author also ran an experiment with nonce words mostly of three syllables, plus only a few of four syllables. The target items were of three types (27 for each type):

(26) a. nonce words with suffixes associated with penultimate stress (e.g. *far.bo+zione*)
b. nonce words without any suffix and with a closed penult XHL (e.g. *pa.sur.co*)
c. nonce words without any suffix with an open penult XLL (e.g. *ma.si.ga*)[30]

[29] However, it could be argued that this distinction is not entirely justified, since, just because a word does not have a recognizable suffix (these words represent only 4% of Kaschny's corpus, 288 of out 7123 words), it does not necessarily mean that the corresponding ending is not associated with a specific stress pattern. For instance, in the morphologically simple word *tesóro* 'treasure', the ending *-oro*, which is not a recognizable suffix used in derived words, is still associated with a specific stress pattern, i.e. mostly stress on the penult, as in *tesóro*, *sonóro*, *lavóro*, *decóro*, *allóro*, *trafóro*, *ristóro*, *castóro* vs *lógoro*, *fósforo*.

[30] It has to be noted that some of the nonce words in the experiment could have, in all three categories, a closed antepenult, since it was assumed that it would not play any role in stress assignment. However, since to my knowledge this has never been thoroughly proved through an extensive experimental study (the only limited data come from Krämer 2009), there is the possibility that the presence of a closed antepenult might have unknowingly played a role in stress assignment, even if a minor one.

The results confirmed the influence of morphology in that the suffixed nonce words were stressed mostly on the penult, although some variation was present for less frequent suffixes (e.g. -*ime*).

In the case of the nonce words without suffix and with a closed penult stress went on the penult about 99% of the time, confirming the weight-sensitivity of a closed penult.

In the case of nonce words without suffix and with an open penult stress went about 65% of the time on the penult.

However, the author notes that, for this type of words, the individual participants tended to show a predilection for either penultimate or antepenultimate stress. If one takes into account this difference, dividing the participants into two groups, it turns out that the group preferring penultimate stress stressed the penult 91% of times, while the group preferring antepenultimate stress stressed the penult only about 39% of the times. The four-syllable nonce words did not seem to significantly differ in stress placement with respect to the three-syllable nonce words.[31]

Therefore, with respect to the nonce words with an open penult, the author concludes that certain speakers prefer to place stress according to the dominant pattern, i.e. collocating stress on the penult, according to the *Penultima-Hypothese*, while other speakers prefer to place stress according to the *Silbenstruktur-Hypothese*, i.e. collocating stress on the penult if it is closed, otherwise mostly on the antepenult.[32]

With respect to the influence of syllable onset on stress assignment, one study by Davis *et al.* (1985) suggests that the onset might play a role in stress assignment in Italian in one specific case, that is in the infinitives of 2nd conjugation verbs. Italian possesses three verbal conjugations:

- 1st conjugation, containing verbs whose infinitive form ends in -*are*, e.g. *amáre* 'to love'
- 2nd conjugation, containing verbs whose infinitive form ends in -*ere,* e.g. *vedére* 'to see'
- 3rd conjugation, containing verbs whose infinitive form ends in -*ire,* e.g. *dormíre* 'to sleep'

In the infinitive forms of the 1st and 3nd conjugation, stress is always on the thematic vowel, i.e. on the penultimate syllable, while the 2nd conjugation contains both infinitives with stress on the penult, e.g. *vedére* 'to see' and infinitives with stress on the antepenult (i.e. on the root vowel), e.g.

[31] However, among the non-suffixed nonce words the ones with four syllables were only 5 of out 27, so the comparison with ones with three syllables should be taken with caution because of the significant difference in the number of items.

[32] However, with respect to this interpretation, it has to be noted that while in the former case the choice is quite categorical (91% on the penult) in the latter case it is rather variable, 61% on the antepenult and 39% on the penult, weakening the hypothesis for the *Silbenstruktur-Hypothese* that there might be a clear-cut rule that collocates stress on the antepenult when the penult is open.

rídere 'to laugh'.[33] With respect to the 2nd conjugation infinitives, Davis *et al.* have noticed that stress goes always on the antepenultimate syllable in the following cases:

(27) a. the antepenult is closed by a consonant[34]

e.g. bát.te.re 'to beat'

b. the antepenult has a simple sonorant onset (i.e. made of /r l m n/)

e.g. rí.de.re 'to laugh'

c. the antepenult has a complex onset (i.e. made of two or three consonants)

e.g. pré.me.re 'to press'

e.g. strí.de.re 'to creak'

In spite of this pattern, in 2nd conjugation infinitives stress can still be found on the antepenult even if none of the three mentioned conditions are met, as can be seen in *de.cí.de.re* 'to decide' or *ví.ge.re* 'to be in force'.

In support of the weight sensitivity of a closed antepenult and of an antepenult with a sonorant onset in 2nd conjugation verbs, the authors also show that many of these verbs actually derive from verbs that in Latin had stress on the penult and that underwent a stress shift to the heavy antepenult, such as it. *rídere* < lat. *ridḗre* 'to laugh' or it. *mór.de.re* < lat. *mor.dḗ.re* 'to bite'. As further evidence, the authors also ran a series of small nonce word experiments with 15 native Italian speakers, from which emerged that made-up 2nd conjugation infinitives with a closed antepenult or an antepenult with a sonorant or complex onset were stressed mostly on the antepenult (> 90%) while more variation was found in the nonce verbs that did not have these conditions.[35]

In conclusion, Italian primary stress is restricted to the last three syllables of a word (except in verbs) and it seems to have a default position on the penultimate syllable. With respect to the influence of syllable weight, a penultimate syllable closed by a consonant attracts stress, while, in 2° conjugation verbs, a sonorant or complex onset or a consonant in the coda in the antepenultimate syllable seem to attract stress. It remains unclear whether overall syllable weight plays a role in the antepenult and in the final syllable. Another open question concerns which other types of syllable

[33] According to the data reported by Davis et al. (1985), the class of 2nd conjugation verbs with stress on the penult comprises 23 verbs (plus some prefixed variants), while the class of verbs with stress on the antepenult comprises about 160 verbs.

[34] With respect to diphthongs, rising diphthongs in the antepenult seem not to count as part of this class, as can be seen from verbs like *pia.cé.re* 'to like', while nothing can be said of verbs with falling diphthong in the antepenult, since none is attested among the 2nd conjugation infinitives.

[35] It must be noted, however, that among the 22 nonce words used, the target words were very few: only 1 word with a closed antepenult (*sencere*), 2 words with a sonorant onset (*letere*, *rocere,* /m/ and /n/ were not tested), 6 words with a complex onset (*plenere*, *procere*, *slenere*, *sletere*, *spenere*, *splenere*), so the results should be taken with caution.

structures besides a consonant in the coda may count as heavy, such as the presence of a diphthong, vowel sonority or onset complexity.

3.3.1 Historical factors and primary stress

Apart from the influence of the different types of syllable structures discussed above, Italian also presents a series of phonological factors, related to its development from Latin, which tend to correlate with specific stress patterns, which are worth taking into consideration when investigating the Italian stress system.

For instance, Italian possesses, among others, the rising diphthongs /jɛ/ and /wɔ/ (corresponding to /je/ and /wo/ in some regions), which were not present in Latin and which developed from stressed short vowels *ĕ* and *ŏ* respectively, when these vowels occurred in an open syllable, as can be seen from the following examples[36] (Patota 2002):

(28)	a. pĕdem	>	piede /ˈpjɛde/	'foot'
	b. bŏnum	>	buono /ˈbwɔno/	'good'

For this reason it can be assumed that, in Italian, syllables with these two diphthongs are correlated with stress. However, it has to be noted that some if these syllables might have ended up in unstressed position in some morphologically complex words, where stress is shifted on a stress-bearing suffix, such as in *sie.ró.so* 'serous' < *sié.ro* 'serum' + -*óso.*

Another historical factor related to stress position in Italian noted by Hayes (2012) concerns the development of vowels *ĭ* and *ŭ* from Latin to Italian. As mentioned further above, in Latin, according to its stress algorithm, if the penultimate syllable is closed by a consonant or ends in a long vowel that syllable is stressed, otherwise stress falls on the antepenult. Thus, in three-syllable words, when Latin had short *ĭ* or *ŭ* in an open penult stress was placed on the antepenult. In the development to Italian these vowels underwent the regular sound change that applies to unstressed *ĭ* and *ŭ,* namely lat. *ĭ* > it. *e* and lat. *ŭ* > it. *o*, as can be seen in the examples a. and b. in (29):

(29)	a. fā́bŭla	>	fávola	'fable'
	b. firmáre	>	fermáre	'to make firm/to stop'
	c. nātū́ra	>	natúra	'nature'

[36] Some exceptions of words that did not undergo diphthongization are also attested, such as *pĕ́coram* > *pécora* /ˈpɛkora/ 'sheep'.

d. actī́vus > attívo 'active'

This means that in Italian three-syllable words, if a word has /i/ or /u/ in the penult, the penult must be stressed, since it means it derives from the corresponding penultimate long vowel in Latin *ī* or *ū*, which was stressed by rule, as can be seen in example 29c-d. On the contrary, if /i/ or /u/ on the penult were not stressed, they would have become *e* or *o*. The presence of an /i/ or /u/ in the penult could thus count as a cue for stress in Italian. However, the above mentioned sound changes occurred only in Italian words which evolved directly from the corresponding Latin ones. Besides these cases, Italian possesses also many 'learned' words (it. *latinismi*), i.e. words which were borrowed from Latin instead of evolving directly from it. In these words, the sound change from unstressed *ĭ* and *ŭ* to *e* and *o,* respectively, did not occur, yielding words like those in (30):

(30)	a. fórmŭla	>	fórmula	'formula'
	b. ắnĭma	>	ánima	'soul'

Therefore, it could be expected that, overall, in Italian /i/ and /u/ in the penultimate syllable should be associated with stress on the penult, unless the word belongs to the 'learned' vocabulary, in which case stress should tend to be associated with the antepenult.

The last historical factor related to stress in Italian concerns the just mentioned *latinismi*. As Hayes (2012) notes, latinate words in Italian tend to be associated with antepenultimate stress.[37] Although there is not an unambiguous way to identify on the segmental level which words are latinate, there are still certain phonological cues which tend to be found almost exclusively in this type of words, specifically certain consonant clusters,[38] such as those in (31) (Tekavčić 1972)[39]:

(31)	a. cl, gl, bl, fl	e.g. glóbo	'globe',	flórido	'flourishing, thriving'
	b. cn, gm, pn	e.g. mágma	'magma',	pneumático	'penumatic'
	c. ps, x /ks/	e.g. psíchico	'psychic',	xilófono	'xylophone'
	d. ct, pt	e.g. pterodáttilo	'pterodactyl',	autóctono	'indigenous'

[37] He notes that this might be also due to the fact that in many learned words a process of syncope was blocked, retaining stress on the antepenult, as in *débĭtus* > *débito* 'debt', while this resulted in penultimate stress in popular words, as in *cómpŭtus* > *cónto* 'count'.

[38] Many of the latinate words are in turn of Greek origin, which accounts for many of the consonant clusters listed in (31).

[39] See this reference for a list of other phonological characteristics of latinate words.

For this reason, it might be possible that the presence of consonant clusters of these types tends to be associated with stress on the antepenultimate, although this is clearly only a tendency and not a categorical rule, as can be also seen from the examples in (29) with penultimate stress.

In conclusion, diphthongs /jɛ/ and /wɔ/ should almost always be stressed, while an /i/ or /u/ on the penult should tend to correlate with stress on that syllable, while the presence of consonant clusters typical of latinate words should tend to correlate with stress on the antepenult. These factors might thus be taken into account when investigating experimentally stress assignment by native Italian speakers.

3.4 Secondary stress and syllable weight in Italian

Whether Italian possesses secondary stress or not has been a matter of debate. However, some phenomena have been identified which might suggest the existence of secondary stress in Italian.

Bertinetto (1976) acknowledges that, in Italian, some long words, such as *vagabondáre* 'to wander', besides primary stress, might have a less prominent stress either on the first or on the second syllable, but he considers this prominence only a rhythmic phenomenon which is applied in order to avoid a long series of unstressed syllables, while he rejects the concept of secondary stress at the phonological level, since there are no minimal pairs based on secondary stress, as in German *ǘbersètzen* 'ferry across' and *ǜbersétzen* 'translate'. Marotta (1999) also doubts the existence of secondary stress, on the basis of the fact that in Italian there are no clear phonological phenomena, like the absence of vowel reduction in English (e.g. *kàngaróo* /ˌkæŋgəˈruː/), that clearly indicate the presence of a secondary stress. Krämer (2009) does not reject the existence of secondary stress altogether but he considers secondary stress to be optional.

One piece of evidence in favor of the existence of secondary stress in Italian comes from the neutralization of /ɛ/ and /ɔ/ in unstressed position. Namely, /E/ and /O/ in Italian surface as the lax vowels /ɛ/ and /ɔ/ only in stressed position, while they are neutralized to [e] and [o] respectively when they become unstressed, such as in /ˈfɔrte/ 'strong' > [forteˈmente] 'strongly'. Camilli (1965) observes that this phenomenon could, at least in some cases, be a hint of the presence of a secondary stress. He notes, for example, that a word like /ˈbɛne/ 'well' gives rise to the adjective /beˈnevolo/ 'benevolent' from which in turn the adverbs which can variably pronounced [ˌbɛnevolˈmente] or [benevolˈmente] are derived, the first of which maintains the lax vowel, suggesting that it might be due to the presence of a secondary stress. However, the author also notes that in the mentioned examples the pronunciation with the lax vowel is not common and restricted only to some speakers.

The retention of the lax vowels can often also be seen in compounds, such as /ˌpɔrtaomˈbrɛlli/ 'umbrella stand', suggesting the presence of a secondary stress, although this does not happen in all cases. Bertinetto and Loporcaro (2005) observe that the likelihood to maintain the lax vowel is correlated to the semantic opacity of the compound and also to the inter-stress interval. For example, the noun *portafogli* 'wallet' (lit. 'carry-papers') tends to be pronounced with the tense vowel /portaˈfɔgli/, since it is not semantically transparent (it is not simply a device to carry sheets of paper) as opposed to *copridivano* /ˌcɔpridiˈvano/ (lit. 'cover-sofa') which is literally an object used to cover a sofa and in which the distance between the two stressed vowels is longer.

Another piece of evidence in favor of the existence of secondary stress in Italian comes from stress retraction (Nespor & Vogel 2007). Stress retraction refers to the fact that, when two stresses happen to occur on two adjacent syllables, one of the two stresses is shifted to a different syllable in order to avoid a stress clash, as can be seen in the following examples:

(32)	a. metá tórta	>	méta tórta	'half cake'
	b. ònoró Búdda	>	ónoro Búdda	'he/she honored Buddha'

(Nespor & Vogel 2007: 174-175)

The authors note that in (32a) main stress of *metá* is shifted to the previous syllable to avoid the stress clash with the initial stress of *tórta*, while in *ònoró* (32b) main stress is shifted not to the previous syllable but rather to the first syllable, as in *ónoro*, suggesting that the first syllable in the original form *ònoró* might have carried a secondary stress.

In addition to the issue of the existence of secondary stress in Italian, a second issue concerns its position within the word, i.e. its directionality. As introduced in sub-chapter 2.3, directionality of secondary stress refers to the way in which a word is parsed into feet depending on the position of secondary stress. Italian seems to show a certain degree of variation in the position of secondary stress, as can be seen from the both possible collocations of a secondary stress in (*càta)maráno* and *ca(tàma)ráno* 'catamaran', the former indicating a directionality from left to right and the latter a directionality from right to left. An accentuation of the type **catamàráno* is instead usually discarded, because it gives rise to a stress clash, which is not deemed possible in Italian.

Vogel and Scalise (1982), who claim that secondary stress position cannot be determined on the basis of phonological information such as minimal pairs or syllable weight, but mostly on a morphological basis,[40] believe that the two possible positions mentioned above depend on factors such as familiarity and context of utterance. For example, a word like *èlettricitá* 'electricity', being a very familiar word, would be pronounced mostly with secondary stress on the first syllable, which is thus considered to be the most natural position, while a word like *encèfalográmma* 'encephalogram', being more unusual, would tend to be pronounced with secondary stress on the second syllable, retaining the original primary stresses of *encéfalo* 'brain' + -*grámma* '-gramm'. They also point out that secondary stress may shift to the second syllable in order to avoid a stress clash with a previous syllable, as in *societá ocèanográfica* 'oceanographic society'.

In spite of the attested variability, various pieces of evidence suggest that Italian has a directionality of secondary stress from left to right, thus collocating secondary stress by default on the first syllable as in *(càta)ma(ráno)* and leaving a syllable unparsed on the right before the foot built around primary stress.

One piece of evidence in favor of a directionality from left to right comes from truncation phenomena (Alber 2009), such as the word *cínema* 'cinema', which comes from the truncation of *cinematógrafo* 'cinematograph'. The author notes that the attested truncatum is *cínema*, with primary stress on the first syllable, instead of **cinéma*, with stress on the penultimate syllable, which is also the default position of stress in Italian, suggesting that the truncated form *cínema* comes from an original form *cìnematógrafo*, with a secondary stress on the first syllable.

Alber (2009), also ran a small experiment with 9 native Italian speakers from the north of Italy, who were asked to read words with a LLLY(X)[41] structure and to judge whether secondary stress falls on the first or on the second syllable or whether it could fall on either syllable. The target words were divided into four categories:

(33) a. no variables (*ca.ta.ma.ra.no*)
b. higher sonority on the second syllable (*di.na.mi.tar.do*)
c. stress preservation on the second syllable (*mo.le.co.la.re*)
d. both higher sonority and stress preservation on the second syllable (*bru.ta.li.tà*)

factor b., refers to the fact that more sonorous vowels might attract stress more than less sonorous vowels, according to the scale a > e, o > i, u. (Kenstowicz 1996), while factor c. refers to the fact that morphologically complex words might retain secondary stress on the vowel that originally

[40] They also postulate a set of rules to determine the position of secondary stress, namely a clash avoidance rule, a stress reversal rule, an initial stress rule and a stress insertion rule (see Vogel and Scalise 1982, pp. 223-238 for a detailed description of these rules).
[41] X referts to any light or heavy syllables, while Y refers to the primary stressed syllable.

carried a primary stress as in *molècoláre* 'molecular' from *molécola* 'molecule' (see sub-chapter 2.3). The results of the experiment are the following:

Table (4). Results of Alber (2007)'s experiment on the directionality of secondary stress in Italian.

	1° syllable	2° syllable	both
1. no variables	70.7%	17.03%	12.22%
2. higher sonority	71.71%	17.17%	11.11%
3. stress preservation	57.33%	27.55%	15.11%
4. both higher sonority and stress preservation	58.58%	32.32%	9.09%
total	**64.01%**	**23.86%**	**12.12%**

As can be seen from table (4), when no variable was present, speakers tended to place secondary stress on the first syllable (70.7%), suggesting a directionality from left to right, while stress preservation on the second syllable increased slightly the percentage of secondary stress on the second syllable (17.17% > 27.55%). No effect of vowel sonority was found.

Another experiment made in the context of a master thesis (Gola 2009) also points to a directionality from left to right. In this study, 17 native Italian speakers from Mantova were asked to read words with the structure XXXY(X) either in a carrier sentence *Ho visto un X* 'I saw a/an X', where X is the target word, or in isolation. In a third task, the participants were asked to read the target word in isolation and then to divide the word into three segments, in order to see how they subdivided the words into feet, e.g. (*pepe*)-*ro*-*náta* vs *pe*-(*pero*)-*náta*. The results are reported in the following table.

Table (5). Results of Gola (2009)'s experiment on the directionality of secondary stress in Italian.

	1° syllable	2° syllable	other
task 1	55.95%	42.25%	1.8%
task 2	81.57%	17.98%	0.45%
task 3 (pronunciation)	87.6%	12.4%	0%
task 3 (chunking)	73.76%	15.38%	10.86%
Average	**72.7%**	**26.4%**	**0.9%**

As can be seen from the percentages of the average calculated from the different tasks, this experiment confirms a directionality from left to right.

With respect to the influence of syllable weight on secondary stress in Italian, it has been shown in the previous section that words with a second syllable closed by consonant like *e.let.tri.ci.tá,* besides the default position of secondary stress on the first syllable, allow some variation, so that both *è.let.tri.ci.tá* and *e.lèt.tri.ci.tá* are possible. However, it remains unclear whether such variation is actually due to the second heavy syllable, since this variation is attested also for words with only light syllables, such as *ca.ta.ma.rá.no.*

To my knowledge no experimental evidence has been provided so far concerning the influence of syllable weight on secondary stress sin Italian . The typological survey presented in chapter (2) shows that when primary stress is sensitive to syllable weight, secondary stress is also sensitive in about 60% of languages while in 40% is not. Since Italian seems to be at least partially sensitive to syllable weight for primary stress, it is reasonable to expect that also secondary stress might show some level of sensitivity.

A preliminary piece of evidence comes from my master thesis (Brugnoli 2019), in which I ran a nonce word experiment with 22 native Italian speakers (16 of which from Verona and the rest from Northern Italy, except one speaker from Rome; age range 14-64), who were asked to read nonce words with LLLYX (e.g. *to.mo.ra.mén.to*) and LHLYX (e.g. *lo.rem.ba.mén.to*) structures, where the heavy syllable H represents a syllable closed by a consonant. Primary stress was triggered on the right edge of the word using real stress-bearing suffixes (e.g. -*ménto*). The expectations were that the participants would place secondary stress mostly on the first syllable in the LLLYX type, confirming a directionality from left to right, and that, if secondary stress is indeed sensitive to syllable weight, they would place secondary stress mostly on the second heavy syllable in the LHLYX type. The collocation of secondary stress was judged by ear. The results are summarized in the table (6).

Table (6). Results of the experiment in Brugnoli (2019) on the directionality of secondary stress and on the influence of syllable weight on secondary stress in Italian.

	1° syllable	2° syllable
LLLYX (e.g. *to.mo.ra.mén.to*)	70.82%	29.17%
LHLYX (e.g. *lo.rem.ba.mén.to*)	9.69%	90.30%

As can be seen from table (6), in the case of the LLLYX type participants collocated secondary stress mostly on the first syllable (70.82% of the times, similarly to previous experiments), confirming a directionality from left to right, while in the LHLYX type they collocated secondary stress on the second heavy syllable 90.30% of the times, suggesting a strong influence of syllable weight, which disrupts the left-to-right directionality.

To sum up, secondary stress in Italian seems to have a default directionality from left to right, thus building a foot at the left margin of the word by placing secondary stress on the first syllable of a word. With respect to the influence of syllable weight, a first experimental approach suggests that a second syllable closed by a consonant attracts stress, although these results need to be replicated with further experiments and possibly using different types of syllable structures.

In conclusion, primary stress in Italian can be described as rightmost, specifically restricted to the last three syllables.[42] When stress is assigned, moraic trochees are formed, leaving the final syllable unparsed, which can be thus considered extrametrical. However, in a small set of words primary stress can fall on the final syllable, building a degenerate foot, e.g. *cittá* H(Ĺ). No stress clash seems to be allowed in any context. With respect to the influence of syllable weight, a penultimate syllable with a consonant in the coda always attract stress, while an antepenultimate syllable with a consonant in the coda, a double or sonorant onset seem to attract stress only in 2nd conjugation verbs. On this basis, primary stress position in Italian can be predicted only in the case of the presence of a heavy penult or in 2nd conjugation verbs, in all other cases it remains unpredictable.

With respect to secondary stress, secondary stress in Italian seems to have a directionality from left to right, i.e. a default position on the first syllable, which can be disrupted almost categorically by a syllable with a consonant in the coda in the second position.

The main stress parameters in Italian are summarized in table (7).

Table (7). Summary of stress parameters in Italian.

Foot	Type	Moraic trochee
	Degenerate foot	Yes
Extrametricality		Yes[43]
Stress clash		No
Primary stress (PS)	Bounded?	Yes, final three-syllable window
	Predictability	Partial
Directionality of PS		Rightmost
Weight sensitivity of PS	Type	Coda[44]

[42] Except in verbs, in which pre-antepenultimate stress is possible in certain inflections.
[43] Except in the very few cases of final stress.

	Categorical?	Yes
Secondary stress (SS)		Yes
Directionality of SS		Left-to-right
Weight sensitivity of SS	Type	Coda
	Categorical?	Yes (~90%)

[44] Also complex onset and sonorant onset only in 2nd conjugation verbs.

4 Stress and syllable weight in German

4.1 The syllable in German

Before analyzing the influence of syllable weight on German primary and secondary stress, the structure of the syllable (and subsequently of the foot, see 4.2) in German will be briefly introduced.

The classical structure of the syllable in German comprises an optional onset, which can be made of up to three consonants, a nucleus, consisting in a short or long vowel, a diphthong or a syllabic consonant, and a coda which can be made of up to three consonants, resulting in a theoretically maximum syllable structure of the type (CCC)V(V/G)(CCC)[45] (Wiese 1996).

With respect to the onset, German allows up to three consonants. However, in sequences of three consonants, the first consonant is always a sibilant /ʃ/ + /p t/ or /s/ + /k/, as in *Spiel* /ʃpi:l/ 'game', so that it may be considered extrasyllabic,[46] restricting the maximum number of consonants in the onset to two, the second of which is usually a sonorant, as in *klein* /klain/ 'small' (Wiese 1996). With respect to the minimal onset structure, although German allows syllables without an onset, a glottal stop is usually inserted before onsetless syllables at the beginning of a root or prefix, or when the syllable is stressed, as in [ʔ]*O*[ʔ]*áse* 'oasis' (Alber 2001).

With respect to the nucleus, it consists of either a vowel, a falling diphthong, e.g. *Reise* /ˈʀaɪ.zə/ or a syllabic consonant (e.g. *lesen* /ˈle:.sn̩/). German distinguishes long and short vowels, which are usually correlated with tenseness, so that long vowels are tense, i.e. /i:/, /e:/, /o:/, /u:/, /y:/, /ø:/, and lax vowels are short, i.e. /ɪ/, /ɔ/, /ʊ/, /ʏ/, /oe/, /ə/. There are however two exceptions, namely the tense vowel /a:/ can also be short /a/, yielding the opposition *Bahn* /ba:n/ 'railway' *vs* *Bann* /ban/ 'ban', and the lax vowel /ɛ/ can also be long /ɛ:/. Furthermore, in spite of the correlation between tenseness and length, short tense vowels can also be found in unstressed position, as in *Metall* /meˈtal/ 'metal'. According to Hall (1992), short tense vowels are actually underlyingly long and they undergo a rule of vowel shortening, while long tense vowels arise only under stress (either primary or secondary), as in *Haustür* /ˈhaʊ̯sˌtyːɐ̯/ 'housedoor' or *Monat* /ˈmo:ˌna:t/ 'month', although it is difficult to establish, especially in the latter example, which is not a compound, whether the second syllable actually bears a secondary stress or not, leaving open also the interpretation of the existence of unstressed long vowels. Féry (2000) claims that, in the case of

[45] In the case of German, VV is used for both a diphthong or a long vowel. In specific cases in which a distinction needs to be made, V: is used to indicate a long vowel and VG to indicate a falling diphthong (G = glide).

[46] According to Wiese (1996) sequences of a sibilant + consonant occupy a single skeletal position in the syllable tier, as it is claimed to be the case also for the affricate mirror sequences made of a stop + a fricative, such as /pf/ and /ts/. However, the extrasyllabicity of intial /ʃ/ and /s/ is not accepted by all scholars, see Wiese 1991 and Wiese 1996 for discussion.

tense vowels, length is not underlying, rather it depends on stress, so that stressed tense vowels become long while unstressed tense vowels do not, while lax vowels are always short irrespective of stress. She also assumes the existence of half-long tense vowels, which surface only word-finally, as in *Auto* /ˈautoˑ/ 'car' or *Monat* /ˈmo:naˑt/ 'month' (Féry 2000: 166-167).

With respect to the coda, it can apparently be made of more than two consonants. However, when a syllable ends with more than two consonants, the consonants beyond the second one happen to always be the coronal obstruents /t/, /d/, /s/, so that these consonants are usually considered extrasyllabic and the maximal coda is thus restricted to two consonants only, as in *Herbst* 'autumn', which can be thus analyzed as having a CVCC<CC> structure (Wiese 1996).

Furthermore, the number of consonants of the coda is restricted by the number of segments (or moras) present in the nucleus, so that a short vowel can be followed by up to two consonants while a long vowel or diphthong can be followed by only one consonant, a regularization which also reinforces the status of /st/ as extrasyllabic, as can be seen in (34):

(34) a. CVCC Dorf 'village'
a. CVVC Raub 'robbery'
b. CVVC<CC> Dienst 'service'

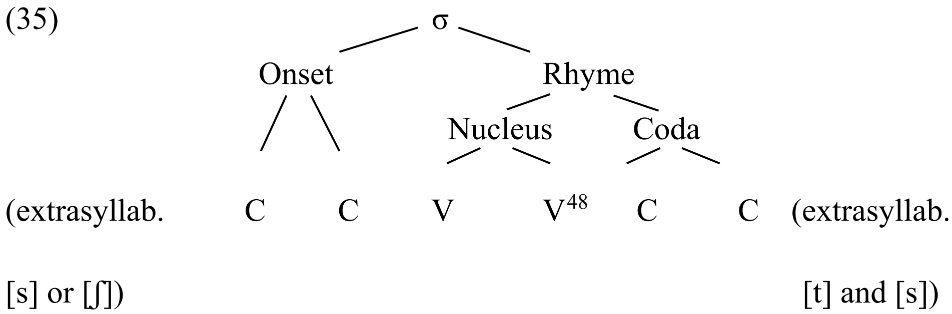
(from Wiese 1996: 37)

Following a moraic approach, the German syllable can thus be considered to have up to three moras, including also no moras, as in the case of syllables ending in a reduced vowel or in a syllabic consonant (Fery 2000). According to some views (Vennemann 1982, Wiese 1996), in cases such as *fallen* /ˈfalən/, the intervocalic /l/ might be considered ambisyllabic, since both /ˈfa.lən/ and /ˈfal.ən/ are possible syllabifications, although the first is more common.[47]

Overall, the structure of the syllable in German can summarized as in (35):

[47] According to Wiese (1996), only an intervocalic consonant following a lax vowel can be ambisyllabic, irrespective of whether stress precedes or follows it.

(35)



(adapted from Alber 2007)

4.2 The foot in German

The German foot has usually been analyzed as a trochee. Wiese (1996) points to the clipping phenomenon observed in hypocoristics, by which a word is usually clipped according to the template of a disyllabic trochee, as in *Wessi* < *Westdeutscher* ‘west German’. The phenomenon of glottal stop insertion before primary and, less often, secondary stress can also, according to Wiese, be unitarily explained by making reference to the notion of a trochaic foot, as in *cha*[ʔ]*ótisch* ‘chaotic’.

Also according to Féry (1995, 2000) German has tendency to build syllabic trochees, and, when not possible, moraic trochees. The trochaic pattern can be seen, for example, from the fact the infinitive forms often present a disyllabic trochaic shape and this is maintained also in contracted infinitive forms, such as *ségeln* ‘to sail’ instead of the dactylic **ségelen,* from *Segel* ‘sail’ plus -*en.* A similar piece of evidence comes from the productivity of the suffix -*ig* which tends to attach to stems which form a disyllabic trochaic shape, such as *ártig* < *Art*, but not **Árbeitig* < *Árbeit.*

Experimental data from a study with nonce words conducted by Janßen (2003) suggests that German speakers realize a variety of trochaic feet, depending mostly on the basis of the structure of the final syllable, which has been found to play a major role in stress assignment in German (see below). These results are also confirmed in an ERPs study manipulating stress position in three-syllable words (Knaus & Domahs 2009), from which the authors conclude that the foot structure that surfaces in German consists in trochees which must be binary at some level of analysis, namely: the disyllabic (ˈLL) and (ˈHL), both found word-internally and word-finally, plus the marked (ˈLH) structure found occasionally only in LLH words, and the monosyllabic bimoraic (ˈH), restricted to word final position, e.g. in (ˌLL)(ˈH).

[48] Here two Vs represent either a long vowel or a falling diphthong.

With respect to degenerate feet, i.e. a foot made of a single open syllable (L), it is usually assumed that this type of foot is not allowed in German, on the basis of the fact that the minimal word structure tends to have a CVV or CVC template, as in *wo* /vo:/ ‘where’ or *mit* ‘with’ (Alber 2009).

4.3 Primary stress and syllable weight in German

Primary stress in German can be found on any of the last three syllables of a word and is thought to be assigned from right to left (Domahs *et al.* 2014a). In the native vocabulary, which, in the case of non-compound forms, is mostly made of one or two-syllable words, stress is often found on the first syllable, as can be seen from example (36a-d). However, especially in the case of monomorphemic longer words, which are usually of Latin or Greek origin, stress can be found on any syllable, apparently irrespective of syllable structure, as can be seen in examples (36e-i) (where L represents an open syllable CV, and H represents a closed syllable CVC).

(36) Native words:

a. Hóse   ĹL   ‘trousers’
b. Séndung   H́H   ‘broadcast’
c. Hímmel   ĹH   ‘sky’
d. Gesétz   LH́   ‘law’

Non-native words:

e. Lógik   ĹH   ‘logic’
f. Musík   LH́   ‘music’
g. Défizit   ĹLH   ‘deficit’
h. Botánik   LĹH   ‘botany’
i. delikát   LLH́   ‘delicate’

As a consequence, the role of syllable weight on primary stress assignment in German has been the subject to extensive debate. Different views have been proposed, ranging from completely weight-insensitive accounts to weight-sensitive accounts that however differ in terms of what types of syllables should count as heavy.

Among the authors who claimed that syllable weight plays no role in the stress system of German, Hall (1992) argues that there is not a strong correlation between stress and heavy syllables, such as syllables closed by a consonant, as can be seen from words like *Energíe*, in which the final syllable is stressed even if the second is heavy. Wiese (1996) notes that a relationship between stress and heavy syllables, e.g. in the form of long vowels, cannot be established, citing pairs of words all with final long vowels, of which only some are stressed as in *Túrba:n vs urbá:n,* concluding that specifically long vowels do not necessarily attract stress. On the basis of the outcome of an experiment in which participants had to read aloud Japanese loanwords, he concludes that stress in German is bound to the last three syllables of a word and that the default position for stress is on the penultimate syllable, while stress on the antepenult or final syllable is marked. He further remarks that words which apparently show a sensitivity to closed syllables, such as *Veránda*, are usually loanwords mostly of Latin or Italian origin which maintain their original stress patterns, according to which a closed penult is usually stressed (see chapter 3).

Among the weight-sensitive accounts, Wurzel (1980) distinguishes between stress in the native vocabulary, which can be derived irrespective of syllable weight, and stress in the non-native vocabulary, in which he notes that a final heavy syllable with a long vowel, a diphthong or a closed syllable attracts stress, i.e. CVV and CVC(C), otherwise stress tends to go on the antepenult or penult.

Giegerich (1985) assumes that CVV(C), CVC and CVCC syllables are heavy, however only word-medially, since he assumes that all word-final consonants are extrametrical, so that in word-final position only CVV(C) and CVCC count as heavy, but not CVC. He concludes that German stress follows a latinate stress rule, according to which stress goes on the final syllable if it is heavy, while if the final is light and the penult is heavy stress goes on the penult, if both the penult and final are light, stress goes on the antepenult.

Vennemann (1990) believes that all syllables that are closed by a consonant or end with a diphthong are heavy, i.e. CVC, CVCC and CVG, and also open syllables that end with a lax/short vowel, i.e. those syllables which could be regarded as ambisyllabic, such as the first syllable in *Gatte,* which could theoretically be analyzed as /ˈgat.tə/ ‘spouse’. On the contrary, open syllables with tense/long vowels are considered light,[49] i.e. CV:. He then proposes that stress goes on the final if it is heavy, otherwise stress tends to go on the penult (except when the penult has a high vowel followed by an onsetless syllable).

According to Féry (1998), only syllables with a long tense vowel plus a consonant or syllables with a short vowel plus two consonants count as heavy, i.e. CVVC, CVCC (that is only those

[49] Vennemann makes the distinction between light and heavy syllables on the basis of his distinction between *smoothly cut* and *abruptly cut* syllables. Smoothly cut syllables are those that present a gradual decrescendo in intensity through the vocalic nucleus and comprise open syllables with tense/long vowels, while abruptly cut syllables are syllables that present a sudden increase in intensity through the vocalic nucleus and comprise syllables with diphthongs and closed syllables with lax/short vowels, including, as mentioned, also possible ambisyllabic syllables, which, as the author notes, historically derive mostly from geminate consonants.

syllables which are traditionally referred to as ‘superheavy’), while syllables with a short vowel plus one consonant or open syllables (both tense and lax) are light, i.e. CVC, CV. In her analysis of monomorphemic words with either two or three syllables made on the CELEX corpus, she confirms that heavy syllables according to her definition tend to attract stress, especially in the case of the final, while if the final is light, stress tends to go on the penult.

The different weight-sensitive accounts of German stress are summarized in table (8).

Table (8). Summary table of heavy and light syllables according to different weight-sensitive accounts of stress in German.

	Light	**Heavy**	**Notes**
Wurzel 1980	CV	CVC, CVCC, CVV	Only in non-native vocabulary
Giegerich 1985	Word-medially: CV Word-finally: CVC	Word-medially: CVC Word-finally: CVV(C) and CVCC	Final consonants are extrametrical (there are no superheavy syllables)
Vennemann 1990	CV:	CVC, CVCC, CVG	CVC comprises also ambisyllabic syllables, as in the first syllable of *Gatte*
Féry 1998	CVC, CV	CVCC, CVVC	Only those syllables which are traditionally referred to as ‘superheavy’ are considered heavy

More recently, a series of experimental studies have shed some light on the role of syllable weight in the stress system of German and on the specific syllable structures that play a role in stress assignment.

Janßen (2003) ran a nonce word reading task, in which 20 monolingual native German speakers, all students at the Heinrich-Heine-Universität Düsseldorf (9 females, 11 males, age range:

19-43) plus 8 informants who participated in a pilot study (5 females, 3 males),[50] were asked to read aloud nonce words with different syllable structures inserted into a carrier sentence.

The nonce words had all three syllables, which could be of the CV, CVC or CVCC type, and were constructed respecting the phonotactics of German and avoiding similarities with existing words. Furthermore they were built avoiding the vowel <e> in penultimate and final position, where it could have been realized as a schwa, and avoiding the vowel <i> in penultimate position, since it seems to be correlated with stress on the antepenult, as in *Éskimo*.

The aim of the experiment was to the test the different hypotheses with respect to the role of different syllable structures in determining stress position, especially on the basis of the final syllable which is thought to play the major role. The theoretical accounts that were tested were those of Giegerich, Vennemann and Féry, plus the accounts that do not assume weight-sensitivity for German stress, which predict stress mostly on the penult.

The different conditions and the results for each conditions are summarized in table (9):

Table (9). Conditions and results of Janßen 2003's nonce word experiment.[51]

		Antepenult	**Penult**	**Final**	**Statistically significant difference**[52]
Final VCC	a. CVC.CV.CVCC	42.9%	10.1%	**47%**	A, F > P
	b. CV.CVC.CVCC	27%	21.6%	**51.4**%	F > A, P
Final VC	c. CVC.CV.CVC	**51.2**%	23%	25.8%	A > P, F
	d. CV.CV.CVC	**42.3**%	19.7%	38%	A, F > P
	e. CV.CVC.CVC	22.8%	**47**%	30.2%	P > A, F
Final V	f. CV.CV.CV	16.6%	**71.5**%	11.9%	P > A, F
	g. CV.CVC.CV	4.8%	**89.6**%	5.6%	P > A, F
	h. CVC.CVC.CV	6.9%	**85.3**%	7.8%	P > A, F

(adapted from Janßen 2003: 70-71)

[50] Overall only the results for 25 participants were inserted in the final analysis.
[51] Besides the main experiment, in the pilot study also some words with a final diphthong plus a consonant were tested, namely VC.V.VGC and V.VC.VGC. In the former the final superheavy syllable was stressed 74% of the times while in the latter the final superheavy syllable was stressed 51.6% of the times, suggesting that these kind of syllables attract more or equally to the VCC syllables.
[52] On the basis of a likelihood ratio test.

As can be seen from the table, if the final syllable is superheavy (CVCC) it receives stress in the majority of cases (a., b.), although, if the antepenult is heavy, stress can go equally on the antepenult or final (a.). If the final is heavy (CVC), stress goes mostly on the antepenult, but also equally on the final (d.). If both the final and the penult are heavy, stress goes mostly on the penult (e.). If the final is light, stress goes overwhelmingly on the penult (f., g., h.), and the percentage on the penult seems to rise if the penult is heavy (g., h.).

More specifically, with respect to the influence of the final, it can be seen that a final CVCC attracts stress more on itself than a final CVC and CV, so there seems to be an effect of rhyme complexity. A final CVC triggers stress mostly on the antepenult or on the final, while, if the final is light, stress falls clearly on the penult, which can also be considered the default position of stress in German, as evidenced particularly by the CV.CV.CV condition, in which syllable weight plays no role since only open syllables are present.

With respect to the influence of the penult, the penult seems to play a role although not as strong as the one of the final, as can be seen when comparing e.g. CV.CV.CVC with CV.CVC.CVC, where the percentages of stress on the heavy penult increases from the former to the latter from 19.7% to 47% and an increase, although smaller, can also be seen in the case of CV.CV.CV *vs* CV.CVC.CV, from 71.5% to 89.6%. On the contrary, a heavy antepenult does not seem to attract stress, since the difference of percentages of stress on the antepenult in CV.CV.CVC *vs* CVC.CV.CVC (from 42.3% to 51.2%) or CV.CVC.CV vs CVC.CVC.CV (from 4.8 to 6.9) were not found to be statistically significant.

On the basis of these results, the author concludes that stress in German can be considered sensitive to syllable weight (where, CVC and CVCC count as heavy and CV as light) and that the structure of final syllable plays the major role in stress assignment, triggering stress either on the antepenult or final. However, also a closed penult attracts stress, especially in the context of a final closed syllable (CV.CVC.CVC), while the structure of the antepenult seems to play no role in stress assignment.

In another study using nonce words, Röttger *et al.* (2012) had 40 native German speakers, all students at the University of Cologne (30 women, 10 men, age range: 18-58, mean age: 23), read nonce words belonging to four categories, reported in table (10): nonce words with a. a heavy final, b. a heavy antepenult, c. a penult with complex onset and d. a final with an orthographically complex rhyme. The types of heavy syllables investigated in conditions a. and b. were CVC, CVG and CVCC. Condition c. investigated disyllabic nonce words with progressively more complex onset in the first syllable, according to the scale V < CV < CCV < CCCV. Condition d. investigated nonce words in which the final syllable was closed by one consonant at the phonological level but the coda phoneme could be represented orthographically by one grapheme, as in *Fo.pun.sas*, where /s/ is represented by <s>, or three graphemes, as in *Fo.pun.sasch*, where /ʃ/ is represented by <sch>. Each condition contains also a control condition, highlighted in grey in table (10), containing a light syllable (CV) in the position in which each target condition would contain a heavy syllable. For example, with respect to condition b., containing a heavy antepenult, CVC.CV.CVC, the control condition would be the CV.CV.CVC condition.

Table (10). Nonce words investigated in Röttger *et al.* (2012)

Condition	**Nonce word**
a. Heavy final	CV.CV.CV
	CV.CV.CVC
	CV.CV.CVG
	CV.CV.CVCC
b. Heavy antepenult	CV.CV.CVC
	CVC.CV.CVC
	CVG.CV.CVC
	CVCC.CV.CVC
c. Complex onset	V.CVCC
	CV.CVCC
	CCV.CVCC
	CCCV.CVCC
d. Orthographically heavy final	CV.CVC.CVC
	CV.CVC.CV<CCC>

The results showed that, with respect to the condition with a heavy final (a.), stress is placed either on the antepenult or on the final, with no statistically significant difference between CVC, CVG and CVCC, although numerically the percentage of stress on the final increases from around 40% for CVC to 53.3% for CVCC, with CVG occupying an intermediate position.

With respect to the condition with a heavy antepenult (b.) the heavy antepenult was found to attract stress more (around 60%) in comparison to a light antepenult (around 48%). However, as for condition a., no statistically significant difference was found between CVC, CVG and CVCC.

With respect to the condition with a complex onset (c.), the percentage of stress was found to increase as a function of onset complexity, from 45.1% to 47.3% to 48.3% to 50.9%, although the increase was not statistically significant.

With respect to condition d., a significant effect of an orthographically complex rhyme was found, since stress fell mostly on the penult in the nonce words in which the coda of the final was represented by one grapheme (CV.CVC.CV<C>), but it fell either on the antepenult or final in the nonce words in which the coda of the final was represented by three graphemes (CV.CVC.CV<CCC>).

These results confirm in part those of Janßen (2003), in that a final heavy syllable triggers stress on either the antepenult or final. They also show that this is the case for both a final diphthong or a final complex coda, both of which however tend to attract stress on the final slightly more than a final simple coda does, raising the question of how they should be categorized phonologically with respect to their influence on stress assignment, especially in the case of a diphthong, whose influence on stress is found to be midway between that of a simple and a complex coda. The results also suggest that, contrary to most accounts of syllable weight in German, also the structure of the antepenult plays a role in stress assignment in German, at least in the case in which also the final syllable is heavy, as was the case in all the items in condition b. which had an HLH structure. With respect to the onset, although it does not seem to play a major role in stress assignment, it still seems to attract stress in a gradient way, in accordance with what was found also in similar studies on other languages (see sub-chapter 2.4). Finally, this study confirms also the influence of the orthographic complexity of the rhyme on stress assignment, a factor which should thus to be taken into account in further studies that make use of nonce words.

In another study, Domahs *et al.* (2014b) compared the results of the experiment conducted by Janßen (2003) with a corpus analysis on the German lexicon using the CELEX corpus.[53] By means of a statistical analysis using CHAID trees, the authors found that the stress patterns related to different combinations of syllable structures found in the nonce word experiment and those found in the corpus analysis matched to a high degree, thus confirming the validity of the results of the nonce word experiment. Furthermore, the authors note that the high degree of accordance between the two analyses tends to speak in favor of an analogical-probabilistic model of stress assignment based on the real lexicon, rather than a rule-based approach by which it would perhaps be expected to find in the lexicon a certain degree of lexicalized forms which do not follow a hypothetical stress-assigning algorithm (so a partial mismatch between the corpus and the experiment), while the speakers would be expected to generalize the stress-assigning algorithm to all the nonce words.[54]

[53] Apart from German, the authors compared the results of a nonce word experiment with a corpus analysis also for English and Dutch.

[54] For a brief discussion concerning the analogical-probabilistic model and the rule-based model of stress assignment and their implications see chapter 8, dealing with the research questions of my own corpus analysis on stress.

Although the role of syllable weight on primary stress has been investigated mostly on three-syllable words (due to the final three-syllable window for primary stress), some experimental evidence has been also provided with respect to four-syllable words. These types of words are of interest because they allow to analyze the interaction between the influence of syllable weight on the position of stress on the one hand and the preference to achieve full parsing of a word into feet on the other hand. For instance, given the tendency of a final heavy syllable to trigger stress on the antepenult or on the final, one possibility would be that in a four-syllable word with a final heavy syllable stress is assigned in the same way as a three-syllable word, meaning that the pre-antepenult is invisible to the stress-assigning algorithm, as exemplified in (37a). On the other hand, another possibility would be that, irrespective of syllable weight, primary stress is assigned to the penultimate syllable building a disyllabic trochee, while a secondary stress is assigned to the pre-antepenult building another disyllabic trochee and achieving full parsing of the word, as in (37b).

(37) a. L(ˈLL)H
b. (ˌLL)(ˈLH)

Janßen (2003) in her above mentioned study on three-syllable nonce words also included 13 four-syllable nonce words as fillers, which had some of the same syllable structures used for the three-syllable nonce words. Overall, the results indicated that the 13 four-syllable nonce words were stressed similarly to the three-syllable nonce words.

One study was also conducted by Ernestus and Neijt (2008), aimed specifically at analyzing whether a difference in stress assignment arises between 3-syllable words *vs* 4-syllable words in German, English and Dutch. With respect to German, the authors analyzed monomorphemic words of three and four syllables (359 in total) in a corpus but they found no statistically significant effect of word length in stress assignment due to the small sample size. They also conducted a nonce word experiment, in which 48 native speakers of German, recruited at the Universities of Cologne, Duisburg, and Kiel, were asked to indicate which was their preferred accentuation for 3-syllable and 4-syllable nonce words, which could either have an open or a closed final syllable.[55] The results indicated that there was a marginally significant higher tendency to put stress on the penultimate syllable in four-syllable word compared with the three-syllable words (from 35.5% to 47.0% for words with a closed final syllable (LLH *vs* LLLH) and from 52.8 to 55.2% for words with an open final syllable (LLL *vs* LLLL), although a considerable degree of individual variation was also

[55] The nonce words were presented in written form in three versions. In each version one of the last three syllables was underlined, representing the stressed syllable. The participants had to mark their preferred stress pattern choosing one of the three possibilities.

found. These results are thus in contrast with those of Janssen (2003), suggesting that more studies are needed to shed light on the relationship between syllable weight and parsing in four-syllables words.

In summary, on the basis of the experimental studies presented so far, it is possible to draw some provisional conclusions with respect to the role of syllable weight in German.

Firstly, it can be safely assumed that syllable weight plays a role in stress assignment, although not in a categorical way as is the case of other languages, such as in Latin.

With respect to the type of syllables that should count as heavy, CVC, CVG and CVCC have proved to influence the collocation of stress, supporting the theoretical account of Wurzel 1980 (although nothing can be said about the distinction between native and non-native vocabulary). Of these three types of heavy syllables, CVCC was found to have a stronger influence than CVC in Janssen (2003) but not in Röttger *et al.* (2012), while CVG, which was investigated only by Röttger *et al.*, was found to have an influence similar to CVC and CVCC.

With respect to the position of heavy syllables, the final syllable has been found to play the major role: if it is heavy, it triggers stress either on the antepenult or on the final, while if it is light, it triggers stress mostly on the penult. A heavy penult was also found to attract stress with respect to a light penult, especially if also the final is heavy, as in CV.CVC.CVC. Also a heavy antepenult was found to attract stress more than an open antepenult, again however only if the final is also heavy, as in CVC.CV.CVC. Onset complexity has not been found to attract stress categorically, but it seems to do so in a gradient way.

With respect to four syllable words, no conclusive evidence has been found concerning the interaction between parsing and syllable weight.

Nothing can be concluded with respect to vowel length, since it has not been investigated in any study, due both to the dubious status of vowel length in German phonology and also to the difficulties in representing it in nonce words. Another parameter which has not been investigated and which could possibly contribute to syllable weight is vowel sonority, which, moreover, has not been controlled for in any of the studies. With respect to the possible positions of the heavy syllables, what emerges from these studies is that in German there is not a specific syllable in one position which exclusively accounts for the entire stress pattern (although, as mentioned, the final syllable seems to exert the major influence), rather the combination of different heavy syllables in different positions seem to interact in a complex way, which thus calls for the need of further studies in which, more specifically, also the influence of the penult and antepenult and of different types of heavy syllables are investigated in more detail.

4.4 Secondary stress and syllable weight in German

As for Italian, in German there are no phonological phenomena that unambiguously point to the existence of secondary stress (such as vowel reduction), nor is secondary stress clearly detectable phonetically (see chapter 13). Nonetheless, some phenomena have been pointed out that at least suggest the existence of secondary stress in German.

For example, Alber (1997a, 2009) recalls the phenomenon of glottal stop insertion in the context of hiatus before primary stress in German and she notes that the same also applies to cases in which there is no primary stress, suggesting it might be triggered by the presence of a secondary stress, as in [ʔ]*Òze*[ʔ]*ànographíe* ‘oceanography’, although she recognizes that this does not happen for all speakers.

Another piece of evidence comes from an experimental study by Domahs *et al.* (2008) using event-related potentials (ERPs), in which the authors artificially manipulated main stress position in words such as *Vitamín,* shifting stress either to the incorrect antepenultimate or penultimate position, as in **Vítamin* and **Vitámin.* They found that stress shift to the penult was associated with a larger positivity effect than a stress shift to the antepenult. The authors interpreted this as evidence that **Vi(tá.min)* involves a restructuring of footing with respect to (*Vì.ta)(mín)* and *(*Ví.ta)(mìn*), both of which build two feet, one with primary stress and one with secondary stress, thus suggesting the presence of a secondary stress at least in words of this structure.

Even assuming the existence of secondary stress, authors differ in their view concerning its exact position in a word, i.e. its directionality and its iterative nature. For instance, Giegerich (1985) notes that in long words a secondary stress can surface on the first and possibly also on the third syllable, as in *Ènzyklòpädíe*, while according to Féry (1995) a secondary stress can be found only on the first syllable and iterative foot formation is avoided, so that all other syllables before primary stress are left unparsed.

One piece of evidence concerning the directionality of secondary stress in German comes from a judgment task conducted by Alber (1997) on 14 native speakers on words with different length and syllable structures. The results indicate that, in words with an LLLY structure, secondary stress tends to go on the first syllable as in *Phìlosophíe*, thus suggesting a directionality from left to right, and also that iterative footing is also possible in longer words, as in (*Àr.gu*)(*mèn.ta*)*tíon.* The results further indicated that in words with an LHLY structure secondary stress can either go on the first light syllable or on the second heavy syllable, as in *Kàleidoskóp* or *Kalèidoskóp,* suggesting an at least variable influence of syllable weight, while in words with an LLLHLY structure the influence of the heavy syllable seemed to be more categorical, as in *Experimèntalísmus*. The results are then accounted for in an OT analysis aimed at modeling the variability of secondary stress which emerged from the experiment.

Vogt (2015) assumes that German words with at least two syllables before primary stress have a secondary stress on the first syllable (i.e. only one syllable before primary stress can be left unparsed and no stress clash is allowed), as suggested by the fact that initial syllables non adjacent to primary stress are never reduced to schwa in German. She also points out to the fact that the productive prefix *ver-* can be attached to verbs such as *spèkulíeren* ‘speculate’ as in *verspekulíeren*, but not to verbs such as *spazíeren* ‘stroll’ as in **verspazíeren*, suggesting that this is due to the fact that the former verbs have a secondary stress on the first syllable, while the latter do not. Similarly, she notes that circumfixation with *ver+ieren* is added to verbs which would have a secondary (or primary) stress on the first syllable, such as *àbsolút* ‘absolute’ > *verabsolutíeren,* but not **absolutíeren,* while in the case of a word without initial stress like *Konsúm* it is possible to have just the suffixed form *konsumíeren.*

An experimental study concerning secondary stress was conducted by Knaus *et al.* (2011), who used ERPs to investigate the collocation of secondary stress in compound words. The items consisted in compounds with a first three-syllable constituent and a second five-syllable constituent, both of which could either have primary stress on the penultimate or on the final syllable, as in the following examples:

(38)	a.	1st penult, 2nd penult	σσ́σ-σσσσ́σ	Európa-Enthusiásmus
		1st final, 2nd penult	σσσ́-σσσσ́σ	Parlaménts-Enthusiásmus
	b.	1st penult, 2nd final	σσ́σ-σσσσσ́	Aróma-Sensibilitä́t
		1st final, 2nd final	σσσ́-σσσσσ́	Aggressións-Sensibilitä́t

The stress of the first constituent, which determines the main stress of the whole compound, remained fixed, while the stress of the second constituent was shifted artificially either to the first or to the second syllable, as in **Európa-Énthusiasmus* or **Európa-Enthúsiasmus*, both of which could theoretically bear a secondary stress. The results showed a larger positivity effect when the stress of the second constituent was shifted to the second syllable than when it was shifted to the first syllable, a result which was also confirmed by a behavioral task that showed that the incorrect position of stress on the second syllable was easier to detect than when stress was shifted to the first syllable. Overall, the fact that stress was processed as more natural on the first syllable in the second constituent of the compound supports a directionality from left to right. Additionally, it was found that the position of main stress in the first constituent did not influence the position of stress in the second constituent, indicating that a stress clash in words like **Aggressións-Sénsibilität* did not seem to influence the prosodic processing of the items.[56]

Noel Aziz Hanna (2003) conducted two experiments, a perception and a production experiment, aimed at investigating the position of secondary stress in word with a primary stress on the last three syllables and also at analyzing the influence of various external factors, including syllable weight.

The perception experiment involved 78 native German speakers, all participants in an introductory seminar on German linguistics (60 females, 18 males). In this study, 19 words with a length from 3 to 7 syllables before primary stress were inserted in a text recorded by two women and one men. The target words contained both open and closed syllables in various combinations. 57 participants (group B) heard the words inside their original phrasal context, while 21 participants (group A) heard the words in isolation (extracted from their original context). Each word was played twice with an interval of 5 seconds and the second time 10 of the 19 words were played in a version extracted from a different context than the first time. All participants received a sheet containing the target words with primary stress underlined and they were asked to underline any other syllables which they perceived as 'stressed' (they could underline any number of syllables, including none). The results showed that the syllable which was indicated the most often as being 'stressed' (i.e. as having a secondary stress) was the first 72.6%, then the second 50.9%, the third 35.0%, the fourth 33.3%, the fifth 24.4%, and the sixth 13.5%,[57] with the results being similar between group A and B. However, the results indicate that the judgment of the position of secondary stress was also influenced by the context in which the word was embedded in the recorded text.

In the production experiment, 40 participants (28 females, 12 males) were recorded while reading aloud 24 words with primary stress on the last three syllables inserted into different carrier sentences. The parameters which were analyzed as possible influences on the position of secondary stress are listed were:

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[56] It is usually assumed that, in monomorphemic words, stress clashes between two secondary stresses or between a primary and secondary stress are avoided in German (Féry 1998,Vogt 2015). However this experiment supports the idea that it is possible in German to have two adjacent stresses at morphological boundaries, as is the case of many compounded words in German, evidenced also from phonetic transcriptions found in dictionary entries, such as for *Háustǜr,* which suggest that native speakers tolerate two adjacent stresses, as long as they are in separate morphemes or roots, one of which might be characterized as a secondary stress. The lack of resolution of a stress clash in compounds is also supported by the results of a series of perception experiments conducted by Wagner and Fischenbeck (2002) on A(BC) compounds, i.e. compounds with a second compound inside the main compound, as in [*Kúnst*[*handwerk*]], from which it emerged that the stress clash between the stresses of the A and the B constituents tended not to trigger a stress shift to the C constituent.

[57] The percentages do not add up because, as mentioned above, for each word more than one 'stress' could be indicated.

(39) a. Rhythmic context

b. Morphological structure of the word

c. Syllable structure

Factor a. refers to the context in which the target word was embedded, and comprised four conditions: the target word could be preceded by a pause, preceded by one stressed syllable, preceded by one unstressed syllable or preceded by two unstressed syllables. Factor b. refers to the morphological transparency of word and comprised three conditions: words whose internal structure was not transparent, words with a prefix and words with transparent internal structure, such as compounds (e.g. *Nitro+phospʰát*) and words with stress preservation (e.g. *Existèntialísmus*). Factor c. refers to different sequences of open and closed syllables before primary stress, which comprised eight conditions: LLL, LLH, LHH, LHL, HHH, HLH, HLL, HHL. The authors and another person naive to the overall goal of the study judged the position of secondary stress by ear[58] and the results were analyzed by means of a logistic regression analysis.

The results with respect to rhythmic context showed that when the target word was preceded by an unstressed syllable secondary stress went mostly on the first syllable, while when the word was preceded by a stressed syllable the percentage of secondary stress on the second syllable increased significantly (although secondary stress was still most often on the first syllable), showing the effect of the stress clash with the previous word. Concerning the influence of the morphological structure of the word, the results indicated that in all three conditions secondary stress fell mostly on the first syllable and the percentage of secondary stress on syllables other than the first was highest in the words whose internal structure was not transparent and lowest in words with transparent internal structure, while words with a prefix occupied an intermediate position. With respect to the influence of syllable structure, the results indicated that the presence of a first or second closed syllable attracted secondary stress, however only in words whose internal structure was not transparent (but irrespective of the rhythmic context).

Through a descriptive analysis using the *Duden Universalwörterbuch* dictionary, the author also impressionistically noted that secondary stress might be influenced by other factors such as vowel sonority, stress preservation, presence of a hiatus and tendency to achieve full parsing, however no definite conclusions could be drawn with respect to these variables since they were not investigated in an experimental setting.

Another smaller experimental study was conducted by me in the context of my master thesis (Brugnoli 2019). In the experiment 7 native German speakers[59] (all females, age range: 57-72 plus

[58] Calculation of Cohen's kappa coefficient revealed that the two ratings were comparable in agreement.

one 32 year-old participant) were asked to read aloud nonce words with a primary stress-bearing suffix on the right with an LLLYX (e.g. *Marapalísmus*) or LHLYX (e.g. *telenkosíeren*) structure, where the heavy syllable H was a syllable closed by a consonant. The expectations were that participants, assuming a directionality from left to right, would place a secondary stress on the first syllable in the LLLYX condition, while assuming an influence of syllable weight, they would place a secondary stress on the second heavy syllable in the LHLYX condition. The results are summarized in (11):

Table (11). Results of Brugnoli (2019)'s experiment on the directionality of secondary stress and on the influence of syllable weight on secondary stress in German.

	1° syllable	2° syllable
LLLYX (e.g. *Marapalísmus*)	95.12%	4.87%
LHLYX (e.g. *telenkosíeren*)	45.04%	54.95%

The results in the LLLYX condition indicated a clear directionality from left to right, since secondary stress was placed overwhelmingly on the first syllable. In the LHLYX condition, secondary stress was placed on the second heavy syllable only about half of the time, thus failing to show a strong influence of syllable weight, although the shift on the second heavy syllable compared with the condition with only light syllables suggest that syllable weight still plays a role in secondary stress assignment in German, although not in a categorical way.

To sum up, the existence of secondary stress in German seems to be suggested by various phonological phenomena and also supported by experimental evidence. With respect to the directionality, the studies so far suggest a directionality from left to right, in line with the directionality assumed also for other Germanic languages (Alber 2020). The rightwards directionality might be disrupted by different phenomena, including syllable weight, although further research is needed in order to have a clearer picture of the role of syllable weight on secondary stress in German.

In conclusion, German primary stress can be described as rightmost, specifically assigned to the last three syllables of a word and as having a default position on the penultimate syllable. With respect to foot type, in German stress assignment there seems to be a tendency to build moraic trochees when possible, e.g. in (L̀L)(H́), but there is also the possibility to resort to syllabic trochees if a parsing using moraic trochees is not possible, e.g. in (ĹH), disallowing degenerate feet, e.g.

[59] The low number of participants was due to the difficulties in finding native German speakers in Verona (Italy), where the experiment was conducted.

*(Ĺ)H. With respect to stress clash, it seems to be generally avoided inside morphologically simple words, but it is probably allowed between words in a compound and perhaps across certain morphological boundaries. With respect to sensitivity to syllable weight, a syllable with a consonant in the coda and a syllable with a diphthong seem to be heavy, although their influence is not categorical. The heavy syllable that seems to exert that the major influence on stress assignment is the final, but also the penult has been shown to exert an influence, while the antepenult seems to play only a minor role in stress assignment. Because of the non-categorical influence of syllable weight, primary stress within the final three-syllable window is not entirely predictable.

With respect to secondary stress, it seems to have a directionality from left to right, i.e. a default position on the first syllable, and to be influenced by the presence of syllable with a consonant in the coda in second position, which disrupt the directionality from left to right, although not in a categorical way.

The main parameters concerning stress in German are summarized in table (12).

Table (12). Summary of stress parameters in German**.**

Foot	Type	Moraic or syllabic trochee
	Degenerate foot	No
Extrametricality		No[60]
Stress clash		No (but allowed at morphological boundaries)
Primary stress (PS)	Bounded?	Yes, final three-syllable window
	Predictability	Partial
Directionality of PS		Rightmost
Weight sensitivity of PS	Type	Coda, Diphthong
	Categorical?	No
Secondary stress (SS)		Yes
Directionality of SS		Left-to-right
Weight sensitivity of SS	Type	Coda
	Categorical?	No

[60] However, in some analyses of antepenultimate stress extrametricality is assumed to be active (see Alber 2020).

5 Nonce word experiment: research questions

The following chapters are aimed at investigating empirically the influence of syllable weight on the stress system of Italian and German through a nonce experiment and a corpus analysis.

As was seen in the previous chapters, syllable weight has been proved to play a role in stress assignment in both Italian and, especially, in German (for which more experimental evidence is available). In both languages however it remains unclear to what extent syllable weight influences the position of primary stress. More specifically, it remains an open question exactly which types of syllables can count as heavy in these languages and in which positions within the word and how these factors interact with one another. Since both Italian and German do not seem to show a categorical influence of syllable weight (as is instead the case, for instance, in a language like Latin, see chapter (2)), another question concerns also the degree of the influence on stress assignment of the different types of heavy syllables in different positions.

With respect to the influence of syllable weight on secondary stress, for both languages (especially for Italian) experimental evidence is scarce, thus this work is aimed at filling this gap by bringing novel results with respect to an issue that has not received much attention so far. As in the case of primary stress, also in the case of secondary stress the question arises of which types of syllables count as heavy and also how sensitivity to syllable weight of secondary stress might differ from sensitivity to syllable weight of primary stress. Furthermore, by investigating the role of syllable weight in secondary stress, this work also addresses the question of the directionality of secondary stress in these two languages, another aspect which has not been extensively researched experimentally.

Overall, the general research questions for both Italian and German that this work aims to address are the following:

Research questions related to primary stress:

1. Is primary stress sensitive to syllable weight and to which extent?
2. What types of syllables count as heavy, i.e. attract stress, and how do different types of heavy syllables differ in their role with respect to stress assignment?
3. What syllable positions within the word are relevant for stress assignment and how do different syllable positions differ in their role in stress assignment?
4. Does syllable weight interact with parsing of a word into feet?

Research questions related to secondary stress:

5. What is the directionality of secondary stress?
6. Is secondary stress sensitive to syllable weight and to which extent?
7. What types of syllables count as heavy, i.e. attract stress, and how do different types of heavy syllables differ in their role with respect to secondary stress assignment?
8. Does secondary stress differ from primary stress in the degree of sensitivity to syllable weight and in the types of syllables that count as heavy?

While these general research questions are common to both Italian and German, the two languages differ however in many aspects related specifically to their stress system or more generally to their phonological system, such as with respect to the different licit syllable structures or to the possible sites for stress assignment within a word. For these reasons, the more specific research questions and hypotheses related to the single languages will be discussed in the relevant chapters dedicated to each language.

As mentioned above, in order to answer these research questions both a nonce word experiment and a corpus analysis are used in this work.

The nonce word experiment is an experimental approach whose validity in analyzing stress assignment has already been tested with various languages. It consists in presenting native speakers with non-existing words, which however respect the phonotactics of the target language. In most experiments, speakers are asked to read aloud the nonce words and the researcher judges the position of stress by ear or by means of an acoustic analysis.

This experimental procedure has the advantage of allowing the researchers to build the items in a way that allows to answer specific research questions (e.g. whether a certain type of syllable in a certain position attracts stress). It also allows to directly investigate the stress patterns in the speaker's mind (i.e. at the *competence* level), avoiding the influence of lexically stored patterns or of other external factors which characterize the real lexicon, such as morphological structure.

The second methodology which is used in this work is a corpus analysis. The corpus analysis consists in analyzing the stress patterns in a large corpus of real words. This allows to investigate how the hypothetical stress assignment algorithm is implemented in the real lexicon.

The results of the corpus analysis are overall supposed to support those of the nonce word experiment. However, in the case of the corpus analysis another research question arises related to how the speakers might generalize to the nonce words the stress patterns based on the real lexicon and consequently to what extent the results of the nonce word experiment and those of the corpus analysis should be expected to coincide. This second issue and the relevant hypotheses will be discussed more in detail in the introductory part to the two corpus analyses in Italian and German.

6 Nonce word experiment: Italian

6.1 Research questions

6.1.1 Research questions concerning primary stress

6.1.1.1 Research questions concerning 3-syllable words

The aim of this experiment is to investigate the role of syllable weight in primary and secondary stress assignment in Italian. As seen in chapter (3), the default position of primary stress is assumed to be on the penultimate syllable and the percentage of stress on the penult has been found to increase in four-syllable words with respect to three-syllable words. With respect to syllable weight, a closed penult seems to attract stress while a closed antepenult does not. However, in 2° conjugation verbs a closed antepenult and a sonorant or complex onset all attract stress.

On this basis, the following experiment is aimed at expanding the typology of potentially heavy syllables in both antepenultimate and penultimate position, testing some syllable structures that have not been investigated so far. The investigated syllable structures are listed in (40).

(40) Investigated syllable structures that might contribute to the formation of heavy syllables with respect to primary stress assignment:

a. Consonant of the coda	CVC	e.g. <u>can.</u>zo.ne	'song'
b. Rising diphthong	CGV	e.g. <u>qua</u>.dro	'picture'
c. Falling diphthong	CVG	e.g. <u>rau</u>.co	'hoarse'
d. Vowel sonority	C/a/[61]	e.g. <u>pa</u>.ne	'bread'
e. Double onset	CCV	e.g. <u>tra</u>.pa.no	'drill'
f. Triple onset	CCCV	e.g. <u>stre</u>.ga	'witch'
g. Historical factors	[see below]	e.g. <u>psi</u>.chi.co	'psychic'/<u>buo</u>.no 'good'

The influence on syllable weight of the coda consonant was already tested in some previous experiments, so the data from the following experiment will be aimed at either confirming or

[61] As will be explained in more detail in the 'Methodology' section (x.x), the most sonorous type of vowel, i.e. the vowel /a/, is investigated as a syllable structure that might contribute to the formation of heavy syllables in comparison to the least sonorous vowels, i.e. /i/ and /u/, which are investigated as syllable structures that might contribute to the formation of light syllables.

challenging the previous results, according to which a closed syllable with a consonant in the coda attracts stress in penultimate position but not in antepenultimate position.

With respect to factors b. and c., diphthongs have been included in the target syllable structures since they have been proved to play a role in stress assignment in some languages, such as in Spanish, in which, furthermore, a difference in the stress-attracting behavior between rising and falling diphthongs was found (Shelton 2007). Furthermore, it has been seen in the literature that, if in a language a closed syllable with an obstruent coda counts as heavy, the language will also tend to count more sonorous codas as heavy, such as a coda with a resonant (Zec 1995, see chapter 2). Since a diphthong might be assumed to be a more sonorous element than a closed syllable, in Italian it is thus expected to attract stress at least in a way similar or perhaps in a stronger way than a closed syllable.

However, in the case of Italian, while a sequence of a vowel plus a glide is usually analyzed as a diphthong, in the case of a glide plus a vowel it is a matter of debate whether these two segments should be analyzed as both belonging to the nucleus, i.e. forming a rising diphthong, or whether the glide should be analyzed as being part of the onset (see chapter 3 and the discussion in Krämer 2009). Therefore, this experiment will also contribute to shed light on this issue, by allowing to see whether rising diphthongs pattern more similarly to falling diphthongs or more similarly to complex onsets with respect to their possible stress-attracting behavior.

Vowel sonority (factor d.) is a factor which has not been extensively investigated experimentally in relation to stress. If this parameter plays a role in stress assignment, the expectation should be that more sonorous segments, i.e. low vowels, should attract stress more than less sonorous segments, i.e. high vowels.

Double and triple onset (factors e. and f.) were also included as objects of analysis since they have been found to attract stress in a gradient way in other languages (e.g. Ryan 2014 for English and Russian). For this reason, should they play a role in stress assignment, also in the case of Italian they are expected to do so only in a gradient way rather than in a categorical one. In line with the results for other languages, the expectations should also be that an onset made of more segments attracts stress more often than an onset with less segments.

Factor g., as explained in chapter 3, refers to the fact that in Italian some syllable structures might attract stress on the basis of the historical development of the language rather than on the actual phonological properties of these syllable structures. The first historical factor investigated is represented by diphthongs /jɛ/ and /wɔ/. These two diphthongs did not exist in Latin and developed in Italian only from stressed *ĕ* and *ŏ*, so in modern Italian they could be expected to be correlated to stress, being stressed in the same position as in the Latin words they were derived from. This might be in contrast with the behavior of the other diphthongs in Italian, which might not be expected to correlate with stress in such as a categorical way, if at all. The second historical factor is represented by some consonant clusters found in onset position, e.g. /kl/, which in the Italian lexicon are found only in words borrowed from Latin, so called *latinismi*. Since *latinismi* in Italian are usually associated with stress on the antepenult, the hypothesis is that the presence of onsets with these consonant clusters should tend to trigger antepenultimate stress. As was the case for the historical diphthongs, the stress-attracting behavior of these historical clusters is assumed to be different from the stress-attracting behavior of double onsets outside of historical clusters. More specifically, the presence of the former in the antepenult is expected to attract stress, while the presence of the latter in the antepenult is not expected to attract stress, on the assumption that the antepenult is not sensitive to syllable weight.

All of the above mentioned factors, except the historical factors, are tested both in the antepenultimate and in the penultimate syllable. The expectations are that, in penultimate position, besides a syllable with a coda consonant, a syllable with a diphthong (perhaps only a syllable with a falling diphthong), and perhaps a syllable with a low vowel should attract stress. A syllable with a complex onset is expected to attract stress in a gradient way.

With respect to the antepenult, neither a syllable with a coda consonant, a diphthong nor a low vowel is expected to attract stress, under the assumption that the antepenult in Italian is invisible to any stress algorithm. Due to the gradient weight of onsets, it is unclear whether this factor could play maybe just a marginal role in antepenultimate position. With respect to the historical factors, the historical diphthongs were tested only in penultimate position and they are expected to always attract stress, while the historical clusters were tested only in antepenultimate position, and they are expected to be correlated with antepenultimate stress. None of the above mentioned syllable structures were tested in the final syllable, since, apart from some loanwords, in the Italian lexicon many of these syllable structures are not found in the final syllable. Furthermore, final stress in the real lexicon, which is overall rare, is usually marked by a graphic accent, as in *però* ‘but’, so that is unlikely that participants would place stress on the final syllable if not marked with such an accent.

6.1.1.2 Research questions concerning 4-syllable words

Another general research question concerns the possible interaction between stress assignment, syllable weight and parsing into feet, which can be seen comparing stress patterns in words with three and four syllables. More specifically, since Italian is assumed to build trochaic feet, it can be hypothesized that in 4-syllable words stress might be placed differently than in 3-

syllable words, since in the former it is possible to parse the entire word into two disyllabic feet, while in the latter case it is not. This can be seen for example comparing an LLL word with an LLLL one. One hypothesis might be that the LLLL word tends to have a higher probability to receive penultimate stress, since this allows to achieve full parsing of the word through the construction of two disyllabic feet, the first of which likely bearing a secondary stress, as in (ˌLL)(ˈLL), which would not be possible if stress falls on the antepenult, as in L(ˈLL)L. On the contrary, in the LLL type, a syllable must be left unparsed irrespective of whether stress falls on the penult or antepenult, yielding L(ˈLL) or (ˈLL)L.

With respect to its interaction with syllable weight, in the case of LHL *vs* LLHL, in LHL syllable weight is expected to play a role, since the heavy penult has been found to attract stress. Therefore, stress is expected to fall mostly on the heavy penult building a bimoraic trochee, i.e. yielding L(Ḣ́)L.

In the case of an LLHL word, the same is expected as for LHL, i.e. stress is expected to fall mostly on the penultimate heavy syllable, so that in the comparison LHL *vs* LLHL, no difference is to be expected and no effect of parsing is visible, since both words would leave a syllable unparsed, yielding L(H́)L and (L̀L)(H́)L, respectively. Even if in LLHL full parsing is given precedence to the effect of syllable weight, stress is still expected to fall mostly on the penult, yielding (L̀L)(H́L).

However, in the case of HLL *vs* LHLL, if the antepenult were found to be heavy, this would cause HLL to receive stress mostly on the antepenult, yielding (H́)LL. In the case of LHLL, if syllable weight is given precedence to full parsing, stress is expected to fall mostly on the antepenult, as in the case of HLL, yielding L(H́)LL. However, if full parsing is given precedence to the effect of syllable weight, stress is expected to fall mostly on the penult, yielding (L̀H)(ĹL). In the case in which the antepenult were not found to be heavy, the expectations would be then the same as for the LLL *vs* LLLL comparison.

6.1.1.3 Summary of research questions concerning primary stress

In (41), a summary of all the research questions concerning primary stress in words with 3 and 4 syllables is provided.

(41) Summary of research questions (Q) and hypotheses (H) related to primary stress assignment.

Q1: Which types of heavy syllables attract stress?

H1.1 A heavy syllable closed by a consonant attracts stress.

H1.2 A heavy syllable with a diphthong attracts stress (possibly more than a heavy syllable closed by a consonant).

H1.3 A heavy syllable with a low vowel attracts stress (in comparison to a light syllable with a high vowel).

H1.4 A heavy syllable with a complex onset (double or triple) attracts stress in a gradient way, i.e. each additional consonant of the onset contributes to increase the weight of the syllable. A heavy syllable with a complex onset (double or triple) also attracts stress in a non-categorical way, i.e. a complex onset (double or triple) only attracts stress to a lower extent than other types of heavy syllables (i.e. not in 100% of cases)

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Q2: In which position within the word do heavy syllables attract stress?

H2.1 A heavy syllable in antepenultimate position does not attract stress.

H2.2 A heavy syllable in penultimate position attracts stress.

Q3: Does stress assignment in 4-syllable words change with respect to 3-syllable words because of the effect of full parsing which is possible in the former but not in the latter?

H3.1 Comparing LLLL and LLL, in LLLL stress falls on the penult more often than in LLL in order to achieve full parsing of the word into trochaic feet.

H3.2 Comparing LLHL and LHL, in LLHL stress falls on the penult as often as in LHL, because the of the effect of syllable weight on the heavy penult, which attracts stress and allows the formation of bimoraic feet in the penultimate syllable. If the heavy penult does not attract stress, the same hypothesis formulated for LLLL and LLL applies (i.e. H3.1).

H3.3 Comparing LHLL and HLL, if the heavy antepenult attracts stress, in LHLL stress falls on the penult more often than in HLL words in order to achieve full parsing of the word into trochaic feet. If the heavy antepenult does not attract stress, the same hypothesis formulated for LLLL and LLL applies (i.e. H3.1).

Q4: Do heavy syllables that contain syllable structures typical of *latinismi* (here called 'historical factors') influence stress assignment differently from the same structures which are not related to that specific historical development?

H4.1: A heavy syllable with an historical diphthong attracts stress (possibly more often than a heavy syllable with a non-historical diphthong).

H4.2: A heavy syllable with an historical cluster in the onset triggers stress on the antepenultimate syllable.

6.1.2 Research questions concerning secondary stress

With respect to the influence of syllable weight on secondary stress, little experimental research has been conducted so far. Previous studies (Alber 2009, Gola 2009, Brugnoli 2019) suggest that secondary stress in Italian has a directionality from left to right, i.e. its default position is on the first syllable of a word. However, the evidence so far suggest that if the second syllable is heavy (more specifically, closed by a consonant), the directionality from left to right tends to be disrupted and stress is placed on the second heavy syllable. The present study thus assumes a directionality from left to right, which will also allow to replicate the results of previous studies. Additionally, the present study is aimed at corroborating the influence of a second heavy syllable on secondary stress assignment and to expand the typology of possible heavy syllables that might disrupt the directionality from left to right. The investigated syllable structures that might contribute to the formation of heavy syllables, which are always analyzed in the second syllable of the word, are the following:

(42) Investigated syllable structures that might contribute to the formation of heavy syllables with respect to secondary stress assignment:

a. Consonant of the coda	CVC	e.g. ma.<u>gaz</u>.ziniére	'warehouse worker'
b. Rising diphthong	CGV	e.g. e.<u>sau</u>.toráre	'to deprive'
c. Falling diphthong	CVG	e.g. a.<u>lie</u>.nazíone	'alienation'
d. Double onset	CCV	e.g. pu.<u>tre</u>.fazióne	'putrefaction'

As can be seen, the investigated syllable structures for secondary stress are only a subset of those analyzed for primary stress. This was due to constraints related to the scope of experiment, which would have otherwise become too long for the participants. Furthermore, the influence of a triple onset might be difficult to investigate in the second syllable, since the first segment of the triple onset (always an /s/) would be probably syllabified as a coda of the previous syllables.

With respect to the investigated factors, a second syllable with a coda consonant, factor a., is expected to attract secondary stress, as was found also in previous experiments and this would also be in line with what was found so far for primary stress. In the case of rising and falling diphthongs, as for primary stress, being the most sonorous type of syllable structure, they are expected to attract stress in the same way or more than a consonant in the coda. However, also in the case of secondary stress the doubt remains whether rising diphthongs should behave like falling diphthongs. Finally, a double onset is expected to attract stress only in a gradient way, i.e. less strongly than the other factors. All these assumptions are based on the idea that primary and secondary stress should show the same sensitivity to syllable weight and to the same types of heavy syllables. Indeed, as it has been shown in chapter 2, a cross-linguistic survey seems to indicate that only a minority of languages show a sensitivity to syllable weight in the case of primary stress but not in the case of secondary stress. However, there remains the possibility that Italian does not follow this tendency, as well as the possibility that primary and secondary stress are both sensitive to syllable weight but in different ways.

(43) Summary of research questions (Q) and hypotheses (H) related to secondary stress assignment.

Q1: What is the directionality of secondary stress?

H1.1 Secondary stress has a directionality from left to right, i.e. its default position is on the first syllable of a word.

Q2: Does a heavy syllable in second position attract secondary stress, disrupting the directionality from left to right?

H2.1 A heavy syllable in second position attracts secondary stress, disrupting the directionality from left to right.

Q2: Which types of heavy syllables attract secondary stress?

H1.1 A heavy syllable closed by a consonant attracts secondary stress.

H1.2 A heavy syllable with a diphthong attracts secondary stress (possibly more than a heavy syllable closed by a consonant).

H1.4 A heavy syllable with a complex onset (double or triple) attracts secondary stress in a gradient way, i.e. each additional consonant of the onset contributes to increase the weight of the syllable. A heavy syllable with a complex onset (double or triple) also attracts secondary stress in a non-categorical way, i.e. a complex onset (double or triple) only attracts secondary stress to a lower extent than other types of heavy syllables (i.e. not in 100% of cases).

6.2 Methodology

In order to investigate the above mentioned research questions, a nonce word reading task has been conducted. In this experiment, 30 native Italian speakers have been asked to read aloud a list of nonce words with different syllable structures in order to see how they assigned stress to the nonce words.

6.2.1 Participants

The participants were 17 females and 13 males, the age range was 21-64 years old with a mean age of 36.6. With respect to age, the participants are not distributed uniformly, so that they can be roughly divided into two groups, one comprising the younger participants: age range 21-37 (14 females and 5 males), with a mean age of 24.6 years old, and the other comprising the older participants: age range 43-64 years old (3 females and 8 males), with a mean age of 56.4. The participants come mostly from Northern Italy, except 2 who come from central and Southern Italy. More specifically, among the participants from Northern Italy, 21 come from Veneto, 5 from Lombardia and 2 from Trentino-Alto Adige. 1 participant come from Lazio in Central Italy and 1 from Puglia in Southern Italy. Therefore, the results of this experiment should be considered representative mostly for the Northern variety of Italian.

All participants were also asked to indicate whether they were bilingual (i.e. whether they spoke a second language natively, besides Italian) and whether they actively spoke a dialect. 1 participant stated to be bilingual Italian-Arabic and 6 participants stated that they spoke a dialect. The relevant information about the participants are summarized in appendix (1). Most of the younger participants were recruited among students at the University of Verona, while the remaining participants were recruited among acquaintances of the author of the study or through other means.

6.2.2 Items

In order to investigate how participants place primary and secondary stress in words with different syllable structures, 105 nonce words were created, divided according to different conditions depending on the specific object of investigation.

In the case of primary stress, 83 nonce words were created, of which 56 were 3-syllable nonce words, while 27 were 4-syllable nonce words. Each of these groups was created according to two major conditions. The first condition consisted in nonce words with only light syllables (LLL and LLLL), which were aimed at analyzing the default position of primary stress. The second condition consisted in nonce words containing a heavy syllable (e.g HLL or LLHL). The items in this set differed with respect to the type of heavy syllable and to the position of the heavy syllable within the word.

With respect to the type of heavy syllables, the investigated syllable structures were: syllables closed in a consonant, syllables containing a rising or a falling diphthong, a double or a triple onset, syllables varying with respect to the sonority of their nucleus and syllables which might be heavy for historical reasons (i.e. containing one type of historical factor). With respect to the syllables closed in a consonant, the consonant in the coda was most often a sonorant (/l/, /r/, /m/, /n), since these are the consonants that can form a CVC syllable in Italian irrespective of the initial consonant of the following syllable. However, some nonce words also contained syllables with obstruent consonants in the coda as part of a geminate (e.g. *ne.loc.co*). With respect to the syllables varying with respect to the sonority of their nucleus, the vowel in the nucleus could be either the low vowel /a/ or the high vowels /i/ or /u/. Since low vowels are more sonorous than high vowels (see chapter 2), the expectations are that syllables containing /a/ in the nucleus form heavy syllables, while syllables containing high vowels in the nucleus form light syllables. With respect to syllables containing a historical factor, as anticipated in section (6.1.1.1), they could contain either the diphthong /jɛ/ and /wɔ/ or some consonant clusters which are typical of *latinismi,* e.g. /kl/ or /ps/[62] (see sub-chapter 3.3). The complete list of items with the exact phonemes that have been used for each syllable structure is given in appendix (3).

With respect to the position within the word, the heavy syllable could be found either in antepenultimate or in penultimate position. This is due to the fact that a final syllable is never found in final position in Italian (with some exceptions mostly due to loanwords), while a heavy syllable in pre-antepenultimate position would not attract stress, since primary stress in Italian is restricted to the last three syllables of a word.[63] Nonce words with an HHL structure, although existing as real words, are also not investigated here, since the presence of two heavy syllables in the same nonce word would not allow to draw clear conclusions with respect to their respective influence on stress assignment.

Not all types of heavy syllables could be investigated in both the antepenultimate and the penultimate position (e.g. a triple onset can only be found word-initial). Furthermore, as can be seen

[62] Some of the consonant clusters present in the *latinismi* are actually of Greek origin, but they are still referred to as characteristics of the *latinismi*, since it is through the *latinismi* these clusters entered the Italian lexicon.

[63] The only case of words that can have pre-antepenultimate primary stress in Italian is represented by verbs (see chapter 3), however all nonce words used in the present experiment are constructed as to resemble nouns, while nonce words resembling verbs are not investigated in the present experiment.

in table (13), not all conditions contained the same number of items, since in some conditions the number of items had to be reduced. This was due to the fact that testing an equal number of items for all possible combinations of heavy syllables in each position would have resulted in an excessively high number of items, making the reading task too long for the participants, giving rise to the possibility that they might start to over-generalize the same patterns due to fatigue or boredom.

All the nonce words were constructed respecting the phonotactics of Italian and avoiding the resemblance to any real word, using my own judgement as native Italian speaker to evaluate whether a certain nonce word might resemble an existing word too closely. The use of any existing morpheme, such as prefixes or suffixes, or any ending that might resemble any existing morpheme was also avoided. This was done in order to prevent the possible influence of stress patterns triggered by morphemes that might be associated with a specific stress position in the real lexicon (see discussion on neighborhood effect (Colombo *et al.* 2014) in chapter 3).

Furthermore, in order to avoid the possible influence of vowel sonority, in all conditions (except the one where vowel sonority was the object of investigation) vowel sonority was kept constant across the vowels of the antepenult and of the penult, so that the vowels of these two syllables could only be either the low vowel /a/, the mid vowels /e/ /o/ or the high vowels /i/ /u/.

In the case of closed syllables, the phoneme /s/ was avoided as consonant of the coda, since it might also be syllabified as the onset of the following syllables, as in the real word *pasta*, which could be syllabified as both *pas.ta* or *pa.sta,* even though the former is believed to be the most likely pattern.[64] The list of all the investigated conditions for primary stress is given in (13) in the case of 3-syllable words and in (14) in the case of 4-syllable words.

Table (13). Conditions of the 3-syllable nonce words for investigating primary stress in Italian.

Structure	**Type of heavy syllable**	**Example**	**Number of items**
LLL	[None]	fa.na.bo	6
HLL	Coda	zen.to.fa	6
LHL		ne.loc.co	6
HLL	Rising diphthong	pia.va.fo	3
LHL		co.ria.ba	3
HLL	Falling diphthong	lau.si.fo	3
LHL		da.nei.pa	3

[64] However, as mentioned in chapter 3, prescriptive Italian grammars promote the syllabification *pa.sta,* a factor that might thus influence the speakers in the syllabification of this type of nonce words.

HLL	Vowel sonority	ra.si.fa	3
LHL		cu.va.fe	3
HLL	Double onset	tra.fa.bo	4
LHL		na.tra.bo	4
HLL	Triple onset	sgre.ve.pa	4
HLL	Historical factor (onset)	psa.na.fo	4
LHL	Historical factor (diphthong)	ga.lie.po	4

Table (14). Conditions of the 4-syllable nonce words for investigating primary stress in Italian.

Structure	**Type of heavy syllable**	**Example**	**Number of items**
LLLL	[None]	me.ro.ne.fa	5
LHLL	Coda	ga.ral.ca.fo	5
LLHL		fa.ra.lan.go	5
LHLL	Rising diphthong	ru.lia.ne.po	3
LLHL		go.na.ria.fo	3
LHLL	Falling diphthong	la.rai.bo.fa	3
LLHL		za.no.rai.po	3

In the case of secondary stress, 22 nonce words were constructed, all with an XXXY(X)[65] structure, where Y represents the syllable bearing primary stress and X any type of syllable, the first or second of which could potentially receive a secondary stress. Primary stress on the right margin of the word was induced by adding real suffixes that bear primary stress, such as *-zióne* (a suffix forming abstract nouns).

As in the case of primary stress, all nonce words were divided according to two major conditions. The first condition consisted in words with only light syllables before primary stress, i.e. LLLY(X). This condition was aimed at investigating the directionality of secondary stress. The expectations were that, if secondary stress has a directionality from left to right, participants would collocate secondary stress on the first syllable. The second condition consisted in words with a second heavy syllable, i.e. LHLY(X) and was aimed at investigating the possible influence of syllable weight on secondary stress. The expectations were that, if secondary stress is sensitive to

[65] The parenthesis indicates that the final syllable after the one bearing primary stress was optional, i.e. it was present only in some items depending on the suffix used.

syllable weight, participants would place secondary stress on the second heavy syllable instead of on its default position on the first syllable.

As for primary stress, nonce words were constructed so to avoid any similarity with existing words and vowel sonority was kept constant between the first two syllables.

Further 19 nonce words were also added in the experiment as fillers. These nonce words were used in order to distract the participants from the target words by varying the structures of the nonce words and also in order to disrupt the prevalent rhythm, which was expected to be associated with penultimate stress. For these reasons, the fillers consisted in 2-syllable words (e.g. *raco*) or 3-syllable words mostly with antepenultimate stress, triggered by adding suffixes associated with antepenultimate stress (e.g. *gorico*), or with final stress, triggered by the use of a graphic accent on the final syllable (e.g. *milutà*), which is the standard way in Italian orthography to represent stressed final syllables. The presence of the real Italian suffixes in the fillers had also the purpose of inducing the participants to believe that they were overall reading a list of Italian words. The list of all the investigated conditions for secondary stress is given in (15).

Table (15). Conditions of the nonce words for investigating secondary stress in Italian.

Structure	**Type of heavy syllable**	**Example**	**Number of items**
LLLY(X)	[None]	lo.ne.ra.ménto	6
LHLY(X)	Coda	la.ran.ca.ménto	6
LHLY(X)	Rising diphthong	fa.rie.no.ménto	3
LHLY(X)	Falling diphthong	gu.lai.ra.zíone	3
LHLY(X)	Double onset	pi.tru.bi.tá	4

6.2.3 Procedure

The participants were asked to read aloud a list of the nonce words. The nonce words were inserted into the carrier sentence *Ha detto di nuovo X*, ‘he/she said X again’, where X represents the target nonce word. The use of the carrier sentence allowed to have all nonce words in the same prosodic context and it was chosen so that it ended with an unstressed syllable (*nuó.vo*), since a final stress in the carrier sentence might have created a stress clash with a following nonce word that might be otherwise stressed on the antepenult. The items in the list were pseudo-randomized in order to avoid long sequences of nonce words with the same structure or in order to avoid repeating patterns in general. The target nonce words were mixed with the fillers nonce words.

The participants were asked to read the entire list once and they were told that, in case they had difficulties in reading aloud a sentence or a word, they could read it again as many times as they wanted. The majority of participants were recorded in a quiet sound-proofed room at the University of Verona while only a small number of participants was recorded at other places. All the participants were recorded with a linear PCM LS-10 Olympus recorder. The position of stress within each nonce word was judged by ear by me. Nonce words that were mispronounced, for example by adding, deleting or swapping sounds, or that were pronounced with hesitation so that it was not possible to clearly judge the position of stress, were taken out of the final analysis.

6.3 Results

The results for primary stress are given in table (16), for 3-syllable nonce words, and in table (17), for 4-syllable nonce words. The results for secondary stress are given in table (19). All tables show for each condition the percentages and the absolute number of times that stress was collocated on a particular syllable. As expected, none of the nonce word was stressed either on the final syllable or on the pre-antepenultimate, so only the data for the antepenultimate and penultimate syllable are reported. The total number of items produced for each category is also given in the rightmost column. The number of items produced that had to be taken out of the analysis because of mispronunciation of the items or unclear stress position were included in brackets beside the total number of items, preceded by a minus sign. Overall, out of a total of 3150 possible realizations of stress among all nonce words, 2967 were included in the final analysis, while 183 (5.80%) had to be discarded. Per each major condition, the realizations were the following: 1632 (-48) for 3-syllable nonce words, 771 (-39) for 4-syllable nonce words and 564 (-96) for the nonce word with secondary stress. For tables (16), (17) and (19), A Chi-square test was conducted between the results of each condition with a heavy syllable and those of the respective condition with only light syllables (e.g. HLL (coda) *vs* LLL, in the case of 3-syllable words). The table cell containing the highest percentage of stress is highlighted in dark blue if the difference with the baseline condition (highlighted in grey) is statistically highly significant ($p < 0.01$) and in lighter blue if the difference is statistically marginally significant ($0.01 \leq p < 0.05$). In the case of table (18), in which the results for 3 and 4-syllable nonce words are compared with one another, the entire row is shaded (using the color-coding explained above) if the difference is statistically significant.

Table (16). Results for the 3-syllable nonce words aimed at investigating primary stress.

Condition	Type of heavy syllable	Structure	Example	Stress on A	Stress on P	Total
1.	[None]	LLL	fa.na.bo	17.41% (31)	82.58% (147)	178 (-2)
2.	Coda	HLL	zen.to.fa	12.50% (22)	87.50% (154)	176 (-4)
3.		LHL	ne.loc.co	0% (0)	100% (177)	177 (-3)
4.	Rising diphthong	HLL	pia.va.fo	15.66% (13)	84.33% (70)	83 (-7)
5.		LHL	co.ria.ba	1.13% (1)	98.86% (87)	88 (-2)
6.	Falling diphthong	HLL	lau.si.fo	7.86% (7)	92.13% (82)[66]	89 (-1)
7.		LHL	da.nei.pa	0% (0)	100% (76)	76 (-14)
8.	Vowel sonority	HLL	ra.si.fa	14.44% (13)	85.55% (77)	90 (-0)
9.		LHL	cu.va.fe	7.77% (7)	92.22% (83)[67]	90 (-0)
10.	Double onset	HLL	tra.fa.bo	16.94% (20)	83.05% (98)	118 (-2)
11.		LHL	na.tra.bo	12.82% (15)	87.17% (102)	117 (-3)
12.	Triple onset	HLL	sgre.ve.pa	11.11% (13)	88.88% (104)	117 (-3)
13.	Historical factor (onset)	HLL	psa.na.fo	15.38% (18)	84.61 (99)	117 (-3)
14.	Historical factor (diphthong)	LHL	ga.lie.po	0% (0)	100% (116)	116 (-4)

Table (17). Results for the 4-syllable nonce words aimed at investigating primary stress.

Condition	Type of heavy syllable	Structure	Example	Stress on A	Stress on P	Total
15.	[None]	LLLL	me.ro.ne.fa	14.18% (20)	85.81%[68] (121)	141 (-9)
16.	Coda	LHLL	ga.ral.ca.fo	13.47% (19)	86.52% (122)	141 (-9)

[66] P = 0.035.
[67] P = 0.033.
[68] This condition contained one item (*bituripo*) which, unlike the others, was mostly stressed on the antepenult. If this item is removed from the analysis, the percentages change strongly, i.e. stress is placed 2.70% of the times on the antepenult and 97.29% of the times on the penult. See discussion at page x.

17.		LLHL	fa.ra.lan.go	0% (0)	100% (149)	149 (-1)
18.	Rising diphthong	LHLL	ru.lia.ne.po	3.52% (3)	96.47% (82) [69]	85 (-5)
19.		LLHL	go.na.ria.fo	0% (0)	100% (83)	83 (-7)
20.	Falling diphthong	LHLL	la.rai.bo.fa	8.23% (7)	91.76% (78)	85 (-5)
21.		LLHL	za.no.rai.po	0% (0)	100% (87)	87 (-3)

Table (18). Comparison of the results of the nonce words with 3 and 4 syllables.

	3-syllable nonce words			**4-syllable nonce words**		
Type of H	**Struct.**	**Stress on A**	**Stress on P**	**Struct.**	**Stress on A**	**Stress on P**
[None]	LLL	17.41% (31)	82.58% (147)	LLLL	14.18% (20)	85.81%[70] (121)
Coda	HLL	12.50% (22)	87.50% (154)	LHLL	13.47% (19)	86.52% (122)
	LHL	0% (0)	100% (177)	LLHL	0% (0)	100% (149)
Rising diphthong	HLL	15.66% (13)	84.33% (70)	LHLL	3.52% (3)	96.47% (82)
	LHL	1.13% (1)	98.86% (87)	LLHL	0% (0)	100% (83)
Falling diphthong	HLL	7.86% (7)	92.13% (82)	LHLL	8.23% (7)	91.76% (78)
	LHL	0% (0)	100% (76)	LLHL	0% (0)	100% (87)

Table (19). Results for the nonce words aimed at investigating secondary stress.

	Type of heavy syllable	**Structure**	**Example**	**Stress on 1° σ**	**Stress on 2° σ**	**Total**
22.	[None]	LLLY(X)	lo.ne.ra.ménto	84.93% (141)	15.06% (25)	166 (-14)
23.	Coda	LHLY(X)	la.ran.ca.ménto	9.20% (15)	90.79% (148)	163 (-17)

[69] P = 0.010.

[70] The LLLL condition contained one item (*bituripo*) which, unlike the others, was mostly stressed on the antepenult. If this item is removed from the analysis, the percentages change strongly, i.e. stress is placed 2.70% of the times on the antepenult and 97.29% of the times on the penult and, if compared with the distribution of the LLL condition, the difference is statistically highly significant ($p < 0.001$). See discussion at page x.

24.	Rising diphthong	LHLY(X)	fa.rie.no.ménto	58.33% (35)	41.66% (25)	60 (-30)
25.	Falling diphthong	LHLY(X)	gu.lai.ra.zíone	20% (15)	80% (60)	75 (-15)
26.	Double onset	LHLY(X)	pi.tru.bi.tá	69% (69)	31% (31)	100 (-20)

6.4 Discussion of results

With respect to primary stress, it can be seen from the results of the LLL condition (1.) in table (16) that, when a 3-syllable word has no heavy syllable, primary stress falls mostly on the penultimate syllable (82.58%), confirming the penult as the default position for primary stress in Italian. A consonant in the coda (3.) attracts stress in 100% of cases. confirming the influence of a closed penult, while, in the case of a closed antepenult (2.), stress is still assigned mostly on the penult (87.50%) and the difference with the LLL condition is not statistically significant, suggesting no influence of a closed antepenult. The results so far are in line with what was found in previous studies (Krämer 2009, Kaschny 2011).

With respect to diphthongs, it can be seen that both a rising and a falling diphthong in the penult (conditions 5. and 7.) attracts stress categorically (98.86% and 100% respectively), i.e. they pattern in the same way as a syllable closed by a consonant. In the antepenult, a rising diphthong (4.) does not attract stress, which goes mostly on the penult (84.33%) as in the LLL condition. In the case of a falling diphthong in the antepenult (6.) there seems to be an unexpected increase of stress on the penult (92.13%) with respect to the LLL condition. However, this increase was found to be only marginally statistically significant ($p = 0.035$) and it could be explained by the fact that of the three items of this condition one (*tairiba*) was stressed almost always on the penult (29 out of 30 realizations),[71] thus skewing the percentage of stress towards the penult. Overall, considering the fact the falling diphthong was on the antepenult and that the antepenult seems not to attract stress in the case of a rising diphthong, there is no reason to believe that the shifts towards the penult is motivated phonologically, so I interpret these results as suggesting that a falling diphthong on the antepenult plays no role in stress assignment.

Additionally, the fact the both types of diphthong behave in the same way (especially in the penult) supports the hypothesis that a glide plus a vowel should actually be analyzed as a diphthong rather than a sequence of a glide in the onset plus a vocalic nucleus (see discussion in

[71] This was the only nonce words with the ending *-iba*. A real word that might have influenced the pronunciation of *tairiba* might have been *diatríba* 'diatribe', possibly the only 3-syllable word with this ending in the real lexicon.

chapter 3), since, at least with respect to stress assignment, the nonce words with this syllable structure pattern as those with a falling diphthong rather than as those a complex onset plus a vocalic nucleus[72] (see further below).

The fact that a syllable with a consonant in the coda in the penult attracts stress categorically is especially expected since it directly reflects the Latin stress algorithm, according to which if the penult is closed by a consonant or contains a long vowel stress goes on the penult, otherwise it goes on the antepenult. On the contrary, the weight-sensitivity of syllables containing a diphthong cannot be directly linked to the Latin stress algorithm. In fact, Latin possessed only the falling diphthongs *au*, *ae*, *oe*, plus the very rare *eu ei*, *ui* and *yi* /yɪ/ (the latter found only in Ancient Greek loans) (Tekavčić 1972). Even if one assimilates these diphthongs to a closed syllable or a long vowel, through an impressionistic search in Latin frequency dictionary (Grifoni & Bucci 2009), it seems however that these diphthongs (which overall are not frequent in the Latin lexicon) are almost never found in penultimate position in 3-syllable words.[73] So it could be assumed that diphthongs did not play any overt role in the stress assigning algorithm in Latin.

With respect to vowel sonority, looking at condition (8.) it can be seen that when there is a low vowel /a/ in the antepenultimate position and a high vowel /i/ or /u/ in penultimate position, the antepenult does not attract stress, which still goes mostly on the penult (85.55%). However, if there is a low vowel penultimate position and a high vowel antepenultimate position (9.), the penult seems to attract stress (92.22%) and the difference is statistically significant (although not strongly, $p = 0.003$) with respect to the LLL condition, suggesting a possible influence of vowel sonority of this type on the penult.

With respect to a double onset (10. and 11.), irrespective of whether the syllable with a double onset is found in antepenultimate or in penultimate position, stress goes mostly on the penult (83.05% and 87.17% respectively) and in neither case the difference is statistically significant with respect to the LLL condition. However, since a complex onset has been found to attract stress only in a gradient and non-categorical way in other languages, it might still be the case that the numerical increase of stress on the penult from 82.58% of the LLL condition to 87.17% of the condition with a double onset in the penult might be due the influence of the onset, which attracts

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72 All the nonce words had an onset, so in a nonce word like *pia.va.fo*, if one assumes that the glide is part of the onset, the first syllable could be analyzed as a having a double onset and it would thus be expected to pattern similarly to a nonce word like *trafabo*.

73 The only apparent exception could be in the perfect tense of the first-conjugation verbs, which is formed with the suffix *-vi* /wi/ added to the verb stem, e.g. *amāvi* /a.ˈma:w.i/ 'I loved' from *amā* + *vi*. However, since in first conjugation verbs the stem vowel *-a-* is always long, it is possible to argue that stress is attracted to the penult by the presence of the long vowel, rather than by the presence of the diphthong. Apart from this exception, diphthongs in Latin can still be found in the penultimate syllable in 2-syllable words, e.g. *poe.na* 'punishment' or *au.rum* 'gold', but since in Latin stress could never fall on the final syllable, in 2-syllable words stress was by consequence always placed on the penult by default, irrespective of syllable structure.

stress only slightly. However, on the basis of these data, there is no way to reach a definitive conclusion.

With respect to a triple onset in antepenultimate position (12.), not only the antepenult does not attract stress, but the percentage of stress on the penult seems even to increase with respect to the LLL condition (88.88% *vs* 82.58%), however the difference has not been found to be statistically significant. Since the first segment of the triple onset was always /s/ (the only phoneme which in Italian is allowed as the first segment of a triple onset), these results also reinforce the interpretation of /s/ as extrasyllabic in this type of onset.

With respect to the historical factor represented by a Latinate cluster in the antepenult (13.), such as *psa.na.fo*, it seems to pattern exactly like the non-Latinate cluster in the onset found in condition 10., such as *tra.fa.bo* (83.05% and 84.61% of stress on the penult respectively), suggesting that it does not play a role in stress assignment.

With respect to the historical factor represented by the diphthongs /wɔ/ and /jɛ/ in penultimate position, they seem to attract stress categorically as expected (100%). However, since, as evidenced from condition 5., this was also the case of any rising diphthong in the penult (98.86%), it is not possible to conclude that these historical diphthongs attract more than any other type of diphthong.

I will now turn to discuss the results for the 4-syllable nonce words, for which only coda consonant, rising diphthong and falling diphthong have been tested as possible heavy syllables. As can be seen from condition 15., if there are no heavy syllables (LLLL) stress seems to fall mostly on the penult (85.81%) in a way similar to the 3-syllable nonce words (82.58% on the penult). However, it has to be noted that one of the 5 nonce words belonging to the LLLL condition, i.e. *bituripo*, was the only one to be stressed mostly on antepenult (17 times of out of 30),[74] thus alone skewing the percentage in favor of antepenultimate stress. In fact, if this anomalous item is taken out of the analysis the distribution of stress changes radically, with only 2.70% of stress on the antepenult and 97.29% of stress on the penult, suggesting a possible influence of the number of syllables in the collocation of stress (see discussion below).

With respect to the conditions with a heavy syllable, as can be seen from condition 17., 19. and 21., if the penult contains a consonant in the coda, a rising or falling diphthong, stress falls categorically on that syllable, and the difference with respect to the LLLL condition is statistically significant. On the contrary, if the heavy syllable is on the antepenult, it does not seem to attract

[74] This was the only nonce word with the ending *-ipo,* which might for some reason be associated with stress on the antepenult. In Italian there are very few words with this ending: on the basis of a search in a corpus (see chapter 9) I could only find: *brádipo*, *pólipo*, *protótipo*, *stereótipo* with antepenultimate stress and *fenotípo*, *genotípo* with penultimate stress. The ones with antepenultimate stress, besides being more, are also more frequent than the ones with penultimate stress, which are technical terms and in which stress might be placed on the penult because of the presence of the word *típo* 'type', which might cause them to be interpreted as compounds and in compounds in Italian stress falls on the second constituent.

stress, which instead goes mostly on the penult, as in the LLLL condition. The only unexpected result is represented by the condition with a rising diphthong in the antepenult (18.), in which the placement of stress on the penult (96.47%) resulted to be statistically significant with respect to the LLLL condition (85.81%). However, as was the case for the falling diphthong in the antepenult in the 3-syllabe nonce words (6.), this increase might simply be due to the segmental structure of the items in this condition rather than to strictly phonological factors.[75]

If one compares the results of the 3-syllable nonce words and those of the 4-syllable nonce words, as shown in table (18), overall, it might look like there is no difference between the two conditions, since the distributions of stress are similar and the difference is almost always not statistically significant, suggesting no effect of parsing in the 4-syllable nonce words. However, as pointed out above, the LLLL condition should perhaps be reconsidered taking out the anomalous item which received stress mostly on the antepenult. Doing so, the resulting distribution for the LLLL condition is 2.70% of stress on the antepenult and 97.29% of stress on the penult and, if compared with the distribution of the LLL condition, the difference is statistically highly significant ($p < 0.001$).

With respect to the conditions with a heavy syllable (either coda consonant or any diphthong) in penultimate position (LHL *vs* LLHL), since a heavy syllable in this position always attracts stress categorically no conclusions can be drawn with respect to the influence of parsing, since both LHL and LLHL behave in the same way with respect to stress assignment.

Looking at the conditions with a heavy syllable in antepenultimate position (HLL *vs* LHLL), it can be seen that, apart from the unexpected case of the rising diphthong, in the case of a coda consonant and falling diphthong the distribution of stress is similar in the HLL and in the LHLL type. On the basis of these data, if one discards the idiosyncratic case of the rising diphthong, it seems that there is a tendency to achieve full parsing in the LLLL condition, i.e. to collocate stress on the penult more often than in the LLL condition, but not in the LHLL condition, in which stress is collocated on the penult as often as in the HLL condition. On the contrary, an effect of parsing in LHLL would have implied to find out that the penult in LHLL is stressed significantly more often than the penult in HLL. One explanation for the tendency to avoid full parsing of the LHLL type to (ˌLH)(ˈLL) might be related to the tendency to avoid the creation of an ĹH trochaic foot, which represents a rather marked structure in the traditional foot typology.

[75] 2 of the 3 items of this condition (*faruatefa* and *baruesapa*) contained the rising diphthong /we/ <ue>, which in Italian is often preceded by /g/ or /k/ e.g. *questo* ‘this’, *guerra* ‘war’. Since in these nonce words /we/ was not preceded by /g/ or /k/, the sequence might have been interpreted as a hiatus, which in turn might have led to avoid the uncommon accentuation *ba.ru.é.sa.pa,* thus placing stress mostly on the penult.

In the next section, the results concerning secondary stress will be discussed. For ease of reference, the table with the results for secondary stress is reported again here.

Table (19) Results for the nonce words aimed at investigating secondary stress.

	Type of heavy syllable	**Structure**	**Example**	**Stress on 1° σ**	**Stress on 2° σ**	**Total**
22.	[None]	LLLY(X)	lo.ne.ra.ménto	84.93% (141)	15.06% (25)	166 (-14)
23.	Coda	LHLY(X)	la.ran.ca.ménto	9.20% (15)	90.79% (148)	163 (-17)
24.	Rising diphthong	LHLY(X)	fa.rie.no.ménto	58.33% (35)	41.66% (25)	60 (-30)
25.	Falling diphthong	LHLY(X)	gu.lai.ra.zíone	20% (15)	80% (60)	75 (-15)
26.	Double onset	LHLY(X)	pi.tru.bi.tá	69% (69)	31% (31)	100 (-20)

As can be seen from table (19), in the condition with only light syllables LLLY (22.), secondary stress is collocated mostly on the first syllable (84.93%), suggesting as expected a parsing (ˌLL)LY, indicating a default directionality of secondary stress from left to right.

With respect to the conditions with a second heavy syllable, as can be seen from condition 23., if the second syllable is closed by a consonant it strongly attracts stress (90.79%), almost categorically, as was also the case of a closed penult for primary stress.

Looking at diphthongs, it can be seen that rising and falling diphthongs seem to show a different behavior with respect to secondary stress. In the case of a rising diphthong (24.) stress is still collocated mostly on the first syllable (58.33%), while in the case of a falling diphthong (25.) stress falls clearly on the second syllable (80%). Therefore, it could be concluded that a falling diphthong in the second syllable clearly attracts secondary stress similarly to a closed syllable. In the case of a rising diphthong instead it seems that it still attracts stress, since the increase of secondary stress on the second syllable with respect to the LLLY condition (41.66% *vs* 15.06% respectively) is still significant, however it does so in a less strong way than a falling diphthong. This could perhaps be due to the ambiguous status of a glide plus a vowel in Italian, which might sometimes not be analyzed as a diphthong. However, it should also be noted that this condition was the one which caused the most problems to the participants, since it contained the highest percentage of realizations that had to be discarded because of difficulties in reading these items, namely 30 realizations had to be taken away out of 90 (30%), suggesting that these items might have looked particularly unnatural to the participants. Related to this aspect, there is also the fact that two of the three items in this category by mistake contained an initial sequence in the first to syllables identical to real words, i.e. *fári* ‘headlights’ in *farienomento* and *lúmi* ‘lamps’ *lumiariezione*, both *fari* and *lumi* having primary stress on the first syllable. This might perhaps have caused a stress preservation as secondary stress on the first syllable. However, to weaken this hypothesis there is the fact that the third item of the condition, *meruolità*, was also stressed mostly on the first syllable, in spite of not containing any part resembling a real word. Another explanation for these results, which might also account for the difficulties in reading these nonce words, might be that in the real lexicon there are very few words with the LHLY(X) structure in which H is a rising diphthong. If one assumes that the stress patterns found in the nonce words are strongly related to the number and frequency of their counterpart in the real lexicon, then the lack of such items in the real lexicon might have led the participants to variably treat the LHLY(X) structure similarly to the LLLY type and sometimes to be influenced by the diphthong, which as seen still counts as heavy for primary stress.

Finally, with respect to a complex onset on the second syllable, it can be seen from condition 26. that secondary stress still goes mostly on the first syllable (69%), however there is still an increase of secondary stress on the second syllable with respect to the LLLY condition (31% vs 15.06% respectively) and the increase is statistically significant. Considering that the onset has usually been found to attract primary stress in a gradient way and non-categorical way, this only slight increase of stress on the second syllable might be interpreted as in line with the specific stress-attracting behavior of complex onsets.

These results concerning the influence of a heavy syllable on secondary stress, confirm the results which were found for primary stress in the case of a syllable closed by a consonant and of a syllable with a falling diphthong. In the case of a rising diphthong, it is difficult to establish whether the only partial influence on secondary stress was due to problems with the items or to the fact that a glide plus a vowel might not count as a diphthong in the case of secondary stress. In the case of a double onset, it seems to attract stress gradiently in the case of secondary stress but the picture is less clear for primary stress, where the increase caused by a double onset on the penult is numerically but not statistically significant. One reason for this might be due to the fact that secondary stress is perhaps a phonological category that is more susceptible to gradient influences, since it is also less prominent perceptually than primary stress and thus more prone to be shifted, as suggested also by the fact that the default pattern of secondary stress can be more easily disrupted by stress preservation (Alber 2009). On the contrary, primary stress is perceptually more salient, is relevant for speech segmentation and in some cases has also a distinctive function, making it perhaps more stable and less prone to be shifted under the influence of some phonological phenomena that have only a gradient influence.

Finally, some data concerning possible external influences due to the individual participants (see appendix (1)) are discussed.

The results of a mixed-effects logistic regression analysis including *Sex*, *Age* and *Region* as predictors suggests a small effect of *Region.* Namely*,* the only participant from Lazio was found to behave differently in terms of stress assignment from participants from Lombardia (estimate = -1.81947, SE = 0.92253, z = -1.972, p = 0.04).

Furthermore, looking at the results for individual participants it is possible to see that a certain individual variability is present. Although throughout the experiment all participants tend to collocate stress mostly on the penult (as expected) a few participants show a significantly higher preference for antepenultimate stress than most other participants. 23 of the 30 participants collocated stress on the antepenult between 0 and 7 times (mode: 3),[76] 2 participants collocated stress on the antepenult 11 times, and 5 participants collocated stress on the antepenult respectively 21, 24, 27, 30 and 32 times.[77] Looking at the stress patterns of these 5 participants, it can be seen that none of the variation concerns the conditions in which the influence of the heavy syllable can be considered categorical, i.e. the conditions with a coda consonant or a diphthong in the penult, in which stress goes almost always on the penult. The increased preference for the antepenult is found instead in all other conditions, without any apparent difference among them, suggesting that the individual grammar of these participants allows more variation than most participants.

Another pattern related to these 5 participants that is worth mentioning concerns the difference between the 3- and 4-syllable nonce words. From the data of these participants it is possible to see that the percentage of stress on the antepenult is concentrated mostly in the 3-syllable nonce words and decreases in the 4-syllable nonce words. For instance, with respect to a rising diphthong, the HLL condition has stress on the antepenult 12/15 of the times, while in the LHLL condition only 2/15 of the times. These data might thus explain why in the general results the effect of the number of syllables appears only weakly: since most participants tended to place stress mostly on the penult already in the 3-syllable words, the difference with the 4-syllable words cannot emerge clearly. However, this difference seems to emerge in the case of the participants that show a

[76] 7 participants collocated stress always on the penult throughout the experiment. One might argue that these participants had not read the words in a natural way, since they do not show any variation, and that their data should be taken out of the analysis. However, as mentioned, stress mostly on the penult is to be expected in a nonce word experiment on Italian and this was indeed the case for most of the participants, among which there was also a relatively high number with only 1 or 2 cases of stress on the antepenult. Therefore, I have decided to consider the realizations of these 7 participants as valid, since overall they are assimilable to those of most other participants.

[77] With respect to the variables age, sex and region, there wasn't a specific one that was common to all or the majority of these 5 participants.

higher tendency to put stress on the antepenult in the 3-syllable nonce words, a tendency which is lowered in the 4-syllable nonce words. On this basis, it might be thus argued that the tendency to achieve full parsing is indeed present, but not always clearly detectable.

6.5 Conclusions

In conclusion, it has been seen that in the case of primary stress, the weight of the syllable in penultimate position clearly plays a role in stress assignment, while the weight of the syllable in antepenultimate position does not seem to play any role. More specifically, a syllable with a consonant in the coda, a rising and falling diphthong in penultimate position attracts stress categorically, without any difference between the three syllable structures. A syllable with a more sonorous vowel in penultimate position also seems to attract stress almost categorically, at least in the case of vowel /a/ in the penult *vs* either vowel /i/ or /u/ in the antepenult. It remains an open question whether this effect emerges also with other vowel oppositions. A syllable with a double onset in penultimate position increases the percentage of stress on the penult but the difference is not statistically significant. However this might still be interpreted as a gradient and non-categorical influence on stress assignment, which is typical of onsets. Although a gradient and non-categorical influence of a triple onset might have been expected also in the antepenult, this was not found to be the case. In the case of the historical factors, a syllable with a Latinate consonant cluster in the onset in the antepenult was expected to attract stress on the antepenult more than a non-Latinate double onset, but this was not the case. On the contrary, a syllable with a historical rising diphthong in penultimate position was found to always attract stress as expected, however since this was the case also for non-historical rising diphthongs, its stress-attracting behavior cannot be attributed to its specific historical development.

With respect to the preference for penultimate stress in 4-syllable words with respect to 3-syllable words in order to achieve full parsing, it has been shown that this preference emerges clearly when comparing the LLL *vs* LLLL type. In the case of LHL *vs* LLHL no difference emerges, since the heavy penults which were tested attract stress categorically in all cases. In the case of HLL *vs* LHLL, there seems to be a higher preference for penultimate stress in 4-syllable words as compared to 3-syllable words, however this emerges only in the data of participants who show higher-than-average preference for antepenultimate stress in the 3-syllable condition.

With respect to secondary stress, the results show a default position of secondary stress on the first syllable in the LLLY condition, confirming a directionality from left to right. With respect to the influence of a second heavy syllable, a syllable closed by a consonant attracts secondary stress categorically. Also a syllable with a falling diphthong and perhaps also one with a rising diphthong attract secondary stress, although the results are less clear in the case of a rising diphthong. A double onset seems to exert a gradient influence on secondary stress.

Overall, these results confirm the role of syllable weight on primary stress with respect to the penultimate syllable and they confirm the influence of syllable weight on secondary stress in the second syllable. With respect to the difference between primary and secondary stress, the results of this experiment seem to indicate that both levels of stress behave similarly with respect to the type of syllables which count as heavy and to the degree according to which they attract stress.

7 Nonce word experiment: German

7.1 Research questions

This sub-chapter gives an overview of the main research questions concerning stress assignment in German that will be tested in the nonce word experiment.

First, the research questions for primary stress will be presented, divided between research questions concerning 3-syllable nonce words, research questions concerning 2-syllable nonce words and research questions concerning 4-syllable nonce words. Subsequently, the research questions for secondary stress will be presented.

7.1.1 Research questions concerning primary stress

7.1.1.1 Research questions concerning 3-syllable nonce words

As was seen in chapter (4), primary stress in German is restricted to the last three syllables of a word and it is assumed to have a default position on the penultimate syllable.

With respect to the influence of syllable weight, although there is no consensus in the literature about exactly which types of syllables count as heavy, experimental studies suggest that a syllable with one or two consonants in the coda (CVC and CVCC) and a syllable with a falling diphthong (CVG) may count as heavy in German, as well as a syllable with a complex onset (CCV or CCCV), although only to a minor degree (Janßen 2003, Röttger *et al.* 2012). With respect to the position of the heavy syllable, the structure of the final syllable has been found to play the most important role (LLH), since in an LLH nonce word stress is clearly displaced from the default position on the penultimate syllable and is placed either on the antepenultimate or on the final syllable. However, also a heavy penult and antepenult have been found to play a role and to attract stress, although only if the final syllable is also heavy (i.e. in HLH and LHH word types).

In spite of the experimental evidence gathered so far, many aspects concerning the influence of syllable weight on stress in German remain unclear, for example with respect to the specific types of syllable structures that might contribute to the formation of heavy syllables and also with respect to the positions in the word in which a specific syllable might count as heavy.

The main research questions that the following experiment is aimed at answering concern thus which exact types of syllable structures count as heavy in German, i.e. attract stress, and how heavy syllables influence stress placement inside the final three-syllable window reserved for stress.

The following experiment is thus aimed at expanding the typology of possible heavy syllables in German, analyzing the role of syllable structures that have not been investigated before, such as syllables varying with respect to the length or the sonority of the vowel in the nucleus. Furthermore, syllable structures that have already been found to form heavy syllables are also analyzed in positions and in word types that have not been investigated before and in positions which have received only limited attention in previous studies, such as the antepenultimate and penultimate positions.

The investigated syllable structures will be tested in words with 2, 3 and 4 syllables, in antepenultimate, penultimate and final position, although not all types of syllable structures will be tested in all positions in all word types (see below), either because certain syllable structures in certain positions are not possible in German (e.g. a triple onset in the penultimate or final syllable) or simply in order to keep the scope of the experiment limited.

The complete list of the investigated syllable structures is reported in (44).

(44) Investigated syllable structures that might contribute to the formation of heavy syllables with respect to primary stress assignment in German.

a. One consonant in the coda	CVC	e.g. Ananas	'ananas'
b. Two consonants in the coda	CVCC	e.g. Argument	'argument'
c. Falling diphthong	CVG	e.g. Polizei	'police'
d. Vowel length	CVV	e.g. Lehrer	'teacher'
d. Vowel sonority	C/a/[78]	e.g. Katapult	'catapult'
e. Double onset	CCV	e.g. Krokodil	'crocodile'
f. Triple onset	CCCV	e.g. Strategie	'strategy'

A syllable with one consonant in the coda (factor a. CVC) has been found to be heavy in previous experiments, i.e. to attract stress, in all positions (antepenultimate, penultimate and final), however not in the same way in each of these positions. The major influence on stress assignment has been found when a CVC syllable is in final position (CV.CV.CVC), in which case stress falls equally either on the antepenult or on the final. Nonetheless, a CVC syllable has been found to attract stress also in antepenultimate and penultimate position, provided however that the final syllable is also

[78] As will be explained in more detail in the 'Methodology' section (x.x), the most sonorous type of vowel, i.e. the vowel /a/, is investigated as a syllable structure that might contribute to the formation of heavy syllables in comparison to the least sonorous vowels, i.e. /i/ and /u/, which are investigated as syllable structures that might contribute to the formation of light syllables.

CVC, so that in both CVC.CV.CVC and CV.CVC.CVC stress falls mostly on the antepenult and on the penult respectively (Janßen 2003, Röttger *et al.* 2012). However, this type of syllable has never been tested so far in antepenultimate position in an HLL structure.

A syllable with two consonants in the coda (b. CVCC) is found only in final position in non-compound words in German, for this reason it can be tested only in this position. This type of syllable has been found to attract stress in final position significantly more often than a CVC syllable by Janßen (2003) but it has been found to attract stress similarly to a final CVC syllable by Röttger *et al.* (2012),[79] so its exact influence on stress assignment is still unclear, specifically with respect to whether it should count as a superheavy syllable or not.

A syllable with a falling diphthong (c. CVG) has been tested in final position (CV.CV.CVG) and antepenultimate position with a final syllable closed by a consonant (CVG.CV.CVC) and in both positions it has been found to attract stress, doing so to the same degree as a CVC or CVCC syllable. Rising diphthongs are not present in the phonology of German, so they have never been tested in nonce word studies and also in the current study they will not be taken into account.

Vowel length (d. CVV) is known to be a factor that can contribute to make syllables heavy cross-linguistically (e.g. in Latin) and to my knowledge it has never been tested as a possible parameter contributing to the formation of a heavy syllable in German. Long vowels in German are mostly stressed, although unstressed long vowels can occasionally be found in words such as *Februar* [ˈfeːbʀuaːɐ̯] or *Monat* [ˈmoːnaːt], although the length of such vowels could alternatively be interpreted as due to the presence of a secondary stress. Because of the apparent strong correlation between vowel length and stress in the German lexicon, it might be the case that syllables with long vowels actually count as heavy in German.

Vowel sonority (d. C/a/) has also never been tested as a possible parameter contributing to the formation of a heavy syllable in German. This parameter, as seen in chapter (2), refers to the fact that syllables with low vowels might count as heavier than syllables with high vowels. Vowel sonority has been found to contribute to syllable weight in some languages, according to the sonority scale /a/ > /e/, /o/ > /i/, /u/ > /ə/ (Kenstowicz 1996), so there is the possibility that it might play a role in stress assignment in German as well.

Onset complexity (factors e. CCV and f. CCCV) has been found to be a parameter which contributes to form syllables that attract stress in different languages (e.g. Ryan 2014 for English), although syllables with complex onsets have been found to attract stress only to a minor extent compared to other types of syllable structures. In German, Röttger *et al*. (2012) found that in a word

[79] In Röttger *et al.* 2012, CVCC was tested also in antepenultimate position (CVCC.CV.CVC) and it was found to attract stress, however this type of word might have also been interpreted as a compound, which is usually stressed on the first constituent in German.

with a complex onset in initial position and a final closed syllable ((C)CCV.CVC) stress tends to fall on the first syllable more often than in a CV.CVC word, and that stress on the first syllable increases as a function of the number of segments in the onset, although the increase of stress on the first syllable remains low. With respect to a syllable with three segments in the onset, CCCV, in German this type of syllable can be tested only in initial position, since, in monomorphemic words, the first segment of the onset might otherwise be syllabified as the coda of the preceding syllable or, alternatively, a nonce word with a non-initial CCCV syllable might be interpreted as a compound. The role of onset complexity has not been investigated in nonce words with more than two syllables yet.

With respect to the position of the potentially heavy syllables in 3-syllable words, among the above mentioned parameters, as seen, CVC, CVCC and CVG have been tested in final position, CVC in penultimate position and CVC, CVG and (C)CCV in antepenultimate position in words with a CVC final.

No heavy syllable has been tested so far in an HLL structure, i.e. in antepenultimate position in a word with a final light syllable. The assumption behind this gap in the experimental studies is that in words with a final light syllable stress falls on the penult by default, as suggested by the results of Janßen (2003) in the case of LLL, LHL and HHL. However, since the antepenult has been found to play a role in HLH words (Janßen 2003, Röttger *et al.* 2012), it might still be possible that the antepenult exerts some influence in attracting stress also in HLL words, which should thus be analyzed experimentally.

The role of the penultimate syllable has also not been extensively investigated, especially in words with a final light syllable. Janßen (2003) found that in a word with a CV.CVC.CV structure stress on the penult increases with respect to CV.CV.CV. Also in a CV.CVC.CVC word, stress falls mostly on the penult compared to a CV.CV.CVC word, in which stress falls about equally on the antepenult and on the final.

The role of the final syllable is the one that has been investigated in most detail, since the final syllable is also the one which is assumed to exert the major influence on stress assignment in German. However, many of the syllable structures mentioned in (44) have not been investigated in this position so far.

Overall, various syllable structures that might contribute to heavy syllables in German have not been studied yet, such as vowel length and vowel sonority, and even in the case of already analyzed syllable structures, different positions in 3-syllable words in German remain still to be investigated, such as HLL, while others have received only limited examination, such as LHL.

In order to close these gaps and to either corroborate or disprove the results of previous studies, with respect to 3-syllable words, the syllable structures in (44) will be tested primarily in HLL, LHL and LLH word types, in order to analyze whether some or all of these syllable structures attract stress in antepenultimate, penultimate and final position respectively.

Four syllable structures, namely a syllable with a consonant in the coda (CVC), a syllable with a diphthong (CVG), a syllable with double onset (CCV) and a syllable with a long vowel (CVV) will also be tested in penultimate position in the LHH structure, where the final syllable is always a syllable with a consonant in the coda, so CV.H.CVC.[80] This type of nonce word is introduced in order to better analyze the role of the structure of the penultimate syllable in attracting stress. More specifically, a pilot study which was conducted with 5 speakers before the main study revealed that, in an LHL nonce word, stress falls mostly on the penult but the difference of percentage of stress on the penult between the LHL and the LLL condition is not large, so that it is difficult to establish whether the penult actually attracts stress in LHL. On the contrary, comparing LLH and LHH might yield more insights on the role of a heavy penult in attracting stress. Specifically, in an LLH word in which the final syllable has a consonant in the coda, CV.CV.CVC, stress is expected to fall mostly on the final instead of on the penult (see Janßen 2003, Röttger *et al.* 2012), so that, if in LHH the heavy penult attracts stress, in LHH we should expect a shift of the percentage of stress from the final to penult compared to the LLH word type, allowing to see more clearly a possible effect of the heavy penult in attracting stress, unlike in the comparison between LLL and LHL.

A summary of the types of heavy syllables and the positions within the word in which they are investigated and their respective nonce word structures for 3-syllable nonce words is given in (45):

(45) Investigated types of heavy syllables, their position within the nonce word and their respective nonce word structure for 3-syllable nonce words.

Position:	Nonce word structure:	Type of heavy syllable:
a. antepenult	HLL	(CVC, CVV, CVG, CCV, C/a/, CCCV)
b. penult	LHL, LHH[81]	(CVC, CVV, CVG, CCV)
c. final	LLH	(CVC, CVV, CVG, CCV, C/a/, CVCC)

[80] Also other syllable structures could have been tested in this word type (e.g. vowel sonority) and the choice to test only these four syllable structures was simply due to limit the scope of the experiment, which would otherwise become too large.
[81] In LHH the final syllable is always CVC, so for this nonce word structure the ‘type of heavy syllable’ refers to the penultimate H syllable.

7.1.1.2 Research questions concerning 2-syllable nonce words

Besides the question of the role in attracting stress of specific syllable structures in specific positions, the question also arises of whether stress assignment might be influenced by the number of syllables in a word, since words with different numbers of syllables can allow different types of parsing into feet. This can be seen when comparing stress assignment in nonce words with 3 syllables to nonce words with 2 or 4 syllables.

The first type of comparison which can be carried out in order to analyze the effect of parsing on stress assignment is between words of 2 and 3 syllables, which allow different types of parsing into trochaic feet.

In particular, in an LL word structure, stress is expected to mostly fall on the penultimate syllable, since the penult is assumed to be the default position of stress in German, thus creating a disyllabic trochee (Ĺ L). On the contrary, in an LLL word, stress is still expected to fall mostly on the penult, but the double possibility in terms of parsing, (ĹL)L or L(ĹL), might cause stress to also fall on the antepenult. Because of this, the percentage of stress on the penult in LLL is expected to be lower than in LL.

With respect to an HL word in comparison to an LHL word, assuming that the heavy syllable (H) does not exert an influence, the expectations are the same as for LL *vs* LLL, i.e. the percentage of times that stress is placed on the penult in HL is expected to be higher than in LHL, because in the case of LHL, unlike for HL, there will be the possibility of both parsing (ĹH)L and L(H́L). On the contrary, if the heavy syllable attracts stress, the expectations are that both HL and LHL might receive an equal amount of stress on the heavy penult, likely forming a bimoraic trochee, i.e. (H́)L and L(H́)L.

With respect to LH *vs* LLH, since a final heavy syllable has been proven to attract stress in 3-syllable nonce words with an LLH structure, also in LH the final syllable, being heavy, is expected to be stressed most of the times, creating a bimoraic trochee L(H́). In the case of LLH, the heavy final is also expected to attract stress, however an LLH word might also tend to receive stress on the antepenult in order to allow full parsing of the word into two bimoraic trochees (ĹL)(H̀). Thus, unlike the LLH structure, where the effect of parsing might also take place shifting stress to the antepenult, the LH structure could be especially informative with respect to the influence of a final heavy syllable, since there is no effect of parsing that might disrupt the effect of syllable weight. For this reason, if a final heavy syllable attracts stress in German, this should clearly emerge in an LH structure, where we would expect the final syllable to receive the highest percentage of stress.

A summary of the types of heavy syllables and the positions within the word in which they are investigated and their respective nonce word structures for 2-syllable nonce words is given in (46).

(46) Investigated types of heavy syllables, their position within the nonce word and their respective nonce word structure for 2-syllable nonce words.

Position:	Nonce word structure:	Type of heavy syllable:
a. penult	HL	(CVC)
b. final	LH	(CVC)

7.1.1.3 Research questions concerning 4-syllable nonce words

The second case in which the effect of parsing into feet can be seen is when comparing words of 3 syllables with words of 4 syllables.

With respect to the influence of full parsing in 4-syllable words (LLLL), the results of two experimental studies conducted so far yielded contrasting results: one study indicated no effect of parsing in 4-syllable words (Janßen 2003) while another study indicated a possible effect of parsing (Ernestus and Neijt 2008).

When no heavy syllable is involved, i.e. when comparing an LLL word with an LLLL word, the expectations are that in both cases stress falls on the penult, since it is the default position of stress. However, the percentage of stress on the penult is expected to be higher in LLLL than in LLL, because the former can allow full parsing, building two trochaic feet (L̀L)(ĹL), the first of which bearing a secondary stress. This is instead not the case in LLL, in which, irrespective of the position of stress, the parsing into trochaic feet always leaves a syllable unparsed, as in (ĹL)L or L(ĹL), since full parsing would imply a degenerate foot, which is usually assumed not to be possible in German, as in *(ĹL)(L̀) and in *(L̀)(ĹL), the latter of which also contains a stress clash.

This tendency to allow full parsing of the word might also emerge in words of 4 syllables containing a heavy syllable. One possibility might be that the tendency to achieve full parsing in 4-syllable words is stronger than the possible influence of syllable weight exerted by the heavy syllable, so that the former overrides the latter. If this is the case, the following predictions can be made.

In the case of HLL *vs* LHLL, if the syllable in antepenultimate position is heavy and thus attracts stress, the formation of a moraic trochee around the heavy syllable in (H́)LL would trigger stress mostly on the antepenult. However, if in LHLL the tendency to achieve full parsing overrides the influence of syllable weight, stress would fall mostly on the penult, as in (L̀H)(ĹL), instead of on the antepenult, as in L(H́)LL. The former structure, however, would still imply the creation of a marked LH trochee. Under the hypothesis that full parsing overrides syllable weight, we would thus expect that in LHLL stress is placed more often on the penult than in HLL.

In the case of LHL *vs* LLHL, if the syllable in penultimate position is heavy and thus attracts stress, the formation of a moraic trochee around the heavy syllable in L(H́)L would trigger stress mostly on the penult. In this case, even under the assumption that the tendency to achieve full parsing overrides the influence of syllable weight, we would still expect stress on the penult, since the structure (L̀L)(H́L) allows both for full parsing and for stress on the heavy syllable. Therefore, we expect no difference in stress assignment between LHL and LLHL.

In the case of LLH *vs* LLLH, if the syllable in final position is heavy and thus attracts stress, in LLH the formation of a moraic trochee around the heavy syllable already allows full parsing, as in (L̀L)(H́). On the contrary, in LLLH full parsing is possible only if stress falls on the penult, as in (L̀L)(ĹH), so that, if full parsing must be achieved, in this type of word stress is expected to fall mostly on the penult, disregarding the final heavy syllable. Under the hypothesis that full parsing overrides syllable weight we would thus expect that in LLLH stress is placed more often on the penult than in LLH.

The opposite scenario for all the above mentioned oppositions of nonce words of 3 and 4 syllables containing a heavy syllable would be one in which the influence of syllable weight is stronger than the tendency to achieve full parsing. Under this hypothesis, all the 4-syllable structures (LHLL, LLHL and LLLH) are expected to behave exactly as the corresponding 3-syllable structures (HLL, LHL and LLH respectively) in terms of stress assignment. For example, under the hypothesis that syllable weight overrides full parsing, when comparing LLH with LLLH we would expect both to receive stress mostly on the final in an equal manner, even if this means leaving one or more syllables unparsed, as in (L̀L)L(H́).

A summary of the types of heavy syllables and the positions within the word in which they are investigated and their respective nonce word structure for 4-syllable nonce words is given in (47).

(47) Investigated types of heavy syllables, their position within the nonce word and their respective nonce word structure for 4-syllable nonce words.

Position:	Nonce word structure:	Type of heavy syllable:

a. antepenult	LHLL	(CVC, CVG)
b. penult	LLHL	(CVC, CVG)
c. final	LLLH	(CVC, CVG, CVCC)

7.1.1.4 Summary of research questions concerning primary stress

Based on the discussion above, the research questions for primary stress assignment in words with 2, 3 and 4 syllables and some hypotheses concerning some of the investigated syllable structures and syllable positions are summarized in (48).

(48) Summary of research questions (Q) and hypotheses (H) related to primary stress assignment.

Q1: Which types of heavy syllables attract stress?

H1.1 A heavy syllable closed by a consonant attracts stress.

H1.2 A heavy syllable closed by two consonants attracts stress (possibly more than a heavy syllable closed by a consonant).

H1.3 A heavy syllable with a diphthong attracts stress (possibly more than a heavy syllable closed by a consonant).

H1.4 A heavy syllable with a long vowel attracts stress.

H1.5 A heavy syllable with a low vowel attracts stress in comparison to a light syllable with a high vowel.

H1.6 A heavy syllable with a complex onset (double or triple) attracts stress in a gradient way, i.e. each additional consonant of the onset contributes to increase the weight of the syllable. A heavy syllable with a complex onset (double or triple) also attracts stress in a non-categorical way, i.e. a complex onset (double or triple) only attracts stress to a lower extent than other types of heavy syllables (i.e. not in 100% of cases).

Q2: In which position within the word do heavy syllables attract stress?

H2.1 A heavy syllable in antepenultimate position does not attract stress, if the final syllable is light.

H2.2 A heavy syllable in penultimate position attracts stress (and this is expected to be more evident in LHH than in LHL).

H2.2 A heavy syllable in final position attracts stress.

Q3: Does stress assignment in 2-syllable words change with respect to 3-syllable words?
(The symbol '>' means 'overrides')

H3.1 In LLL *vs* LL:

- stress is expected to fall more often on the penult in LL than in LLL because of the tendency to achieve full parsing in the former but not in the latter.

H3.2 In LHL *vs* HL:

- If Full parsing > syllable weight: stress is expected to fall more often on the penult in HL than in LHL, because of the tendency to achieve full parsing in the former (H́L) but not in the latter.
- If Syllable weight > Full parsing: stress is expected to fall equally on the penult in HL and in LHL.

H3.3 In LLH *vs* LH:

If Full parsing > syllable weight: stress is expected to fall more often on the final in LH than in LLH, because of the tendency to achieve full parsing in the latter, causing stress also to fall on the antepenult, yielding (ĹL)(H̀) or (L̀L)(H́).

- If Syllable weight > Full parsing: stress is expected to fall equally on the final syllable in LH and LLH.

Q4: Does stress assignment in 4-syllable words change with respect to 3-syllable words?
(The symbol '>' means 'overrides')

H4.1 In LLL *vs* LLLL:

- stress is expected to fall more often on the penult in LLLL than in LLL because of the tendency to achieve full parsing in the former but not in the latter.

H4.2 In HLL *vs* LHLL, LHL *vs* LLHL and LLH *vs* LLLH:

- If Full parsing > syllable weight: stress is expected to fall more often on the penult in 4-syllable nonce words than in the 3-syllable nonce words because of the tendency to achieve full parsing in the former but not in the latter (except for in the comparison LHL *vs* LLHL, in which stress is expected equally on the penult in both types of words).
- If Syllable weight > Full parsing: stress is expected to fall equally on the heavy syllable in both the 3-syllable and the 4-syllable nonce words.

7.1.2 research questions concerning secondary stress

With respect to secondary stress in German, the evidence from experimental studies conducted so far (Alber1997, Noel 2003, Brugnoli 2019) suggests that secondary stress has a directionality from left to right, i.e. it is collocated by default on the first syllable of a word, and that a syllable closed by a consonant (CVC) in second position tends to attract secondary stress.

The present study is aimed at confirming the directionality from left to right and at expanding the typology of possible heavy syllables that might influence secondary stress assignment. The investigated syllable structures, which are always analyzed in the second syllable of the word, are reported in (49).

(49) Investigated syllable structures that might contribute to the formation of heavy syllables with respect to secondary stress assignment in German.

a. One consonant of the coda	CVC	e.g. A.<u>dap</u>.ta.tión
b. Falling diphthong	CVG	e.g. Res.<u>tau</u>.ra.tión
c. Double onset	CCV	e.g. Re.<u>pro</u>.duk.tión

As can be seen, the investigated syllable structures for secondary stress are only a subset of those analyzed for primary stress. This was due to constraints related to the scope of experiment, which would have otherwise become too long for the participants if all the structures mentioned in (44) were investigated also in the case of secondary stress. Furthermore, the influence of a syllable with a triple onset (CCCV) might be difficult to investigate in the second syllable, since the first segment of the triple onset (always an /s/) would probably be syllabified as a coda of the previous CV syllable. The influence of a syllable with two consonants in the coda (CVCC) might also be difficult to investigate in the second syllable, since its presence in a position other than the final might cause the whole word to be interpreted as a compound, since syllables with a complex coda are only found in final position in non-compound words.

With respect to the possible influence of the investigated syllable structures on secondary stress, a syllable with one consonant in the coda (CVC) is expected to attract secondary stress based on the results of previous experimental evidence and on the fact that this type of syllable has been proved to attract primary stress.

With respect to a syllable with a falling diphthong (CVG), it might be expected to attract secondary stress in the same way or slightly more often than a syllable with a consonant in the coda, since this was found to be the case for primary stress.

With respect to a syllable with a double onset (CCV), it might be expected to attract secondary stress only to a low extent, as was found in the case of primary stress.

The research questions for secondary stress assignment and some hypotheses are summarized in (50).

(50) Summary of research questions (Q) and hypotheses (H) related to secondary stress assignment.

Q1: What is the directionality of secondary stress?

H1.1: Secondary stress has directionality from left to right, i.e. its default position is on the first syllable.

Q2: Which types of heavy syllables attract secondary stress?

H2.1: A syllable closed by a consonant attracts secondary stress.

H2.2: A syllable with a diphthong attracts secondary stress (possibly more than a heavy syllable closed by a consonant).

H2.3: A heavy syllable with a double onset attracts secondary stress in a non-categorical way, i.e. it attracts secondary stress only to a lower extent than other types of heavy syllables (i.e. not in 100% of cases).

Q3: In which position within the word do heavy syllables attract secondary stress?

H3.1: A heavy syllable attracts secondary stress in second position, disrupting the directionality from left to right.

7.2 Methodology

In order to investigate the above mentioned research questions, a nonce word reading task has been conducted. In this experiment, 30 native German speakers have been asked to read aloud a list of nonce words with different syllable structures in order to see how they assign stress to the nonce words.

7.2.1 Participant

Of the 30 participants in the experiment 23 were females and 7 were males, with an age range of 21-48 years and a mean age of 26.8. The participants were mostly in the range 21-30 years old, with only 3 participants being 37, 42 and 48 years old. The vast majority of the participants were recruited among students at the University of Marburg.

With respect to the place of origin, the participants come from different *Länder* (states) of Germany, mostly from the Centre-West and South-West part of Germany, namely: 7 from Hessen, 6 from Baden-Württemberg, 5 from Bayern, 5 from Nordrhein-Westfalen, 4 from Niedersachsen, 1 from Sachsen, 1 from Sachsen-Anhalt and 1 from Mecklenburg-Vorpommern.

All participants were also asked to indicate whether they were bilingual (i.e. whether they spoke a second language natively, besides German) and whether they actively spoke a dialect. 3 participants stated that they spoke a dialect.

The relevant information about the participants is summarized in appendix (2).

7.2.2 Items

In order to investigate how participants collocate primary and secondary stress in words with different syllable structures, 120 nonce words were created, divided into different conditions depending on the specific object of investigation.

With respect to primary stress, 173 nonce words were created, of which 10 were 2-syllable words, 70 were 3-syllable nonce words, while 24 were 4-syllable nonce words. As already mentioned above, the difference in number between the items of the 2-, 3- and 4-syllable nonce words is due to the fact that testing the same number of items for all types of nonce words would have resulted in an excessively long experiment, so that in that case of 2- and 4-syllable nonce word only the syllables structures which are most clearly expected to contribute to weight-effects were used.

Each of these three groups contained two major conditions. The first condition consisted in nonce words with only light syllables (LL, LLL and LLLL respectively), which were aimed at eliciting the default position of primary stress. The second condition consisted in nonce words containing a heavy syllable (e.g. HL, LLH, LLHL, etc.). The items belonging to this condition differed with respect to the type of heavy syllable (e.g. syllable with a consonant in the coda (CVC), syllable with a diphthong (CVG), etc.) and with respect to the position of the heavy syllable within the word (antepenult, penult or final).

In order to assess the role of a possible heavy syllable in attracting stress, the distribution of stress in each condition containing a heavy syllable is compared with the distribution of stress in the baseline condition containing only light syllables. For example, the distribution of stress in an HLL nonce word is compared with the distribution of stress in an LLL nonce word, in order to see whether in HLL stress is placed more often on the heavy antepenult in comparison to LLL.

With respect to the types of heavy syllables, the investigated syllable structures are listed in (44), reported again below in (51) for ease of reference, namely: syllables with a consonant in the coda (CVC), syllables with two consonants in the coda (CVCC), syllables containing a falling diphthong (CVG), syllables containing a long vowel (CVV), syllables varying with respect to the sonority of the vowel in the nucleus (C/a/), syllables with a double onset (CCV) and syllables with a triple onset (CCCV).

(51) Investigated syllable structures that might contribute to the formation of heavy syllables with respect to primary stress assignment in German.

a. One consonant of the coda	CVC	e.g. Ananas	'ananas'
b. Two consonants of the coda	CVCC	e.g. Argument	'argument'
c. Falling diphthong	CVG	e.g. Polizei	'police'
d. Vowel length	CVV	e.g Lehrer	'teacher'
d. Vowel sonority	C/a/	e.g. Katapult	'catapult'
e. Double onset	CCV	e.g. Krokodil	'crocodile'
f. Triple onset	CCCV	e.g. Strategie	'strategy'

With respect to syllables containing one or two consonants in the coda, the phonemes in the coda were not restricted to a specific category and could be any phoneme that can be found in a coda according to the German syllable structure.

Concerning syllables containing long vowels, vowel length was represented using a vocalic grapheme, e.g. <a>, plus the grapheme <h>, so that, for example, a long /a:/ is represented as <ah>, in accordance with how German orthography represents long vowels, as in *fahren* /fa:rən/ 'drive'.[82] However, vowel length in German is not necessarily explicitly represented at the orthographic level (e.g. *Ton* 'tone' and *Lohn* 'salary' both contain long vowels), so that a certain degree of variability is present with respect to the pronunciation of a vowel as long or short and the same vowel in a

[82] Long vowels in German are also represented by doubling the grapheme representing the vowel, e.g. <oo> as in *Boot* /bo:t/ 'Boat'. However this is less common than the combination of a grapheme representing a vowel + <h>.

specific word might be pronounced long by some speakers but short by others, as might be the case of the vowel <o> in *Obst* 'fruit'. In the case of the nonce words, there was no way to prevent this possible variability related to the single speakers.

With respect to syllables varying with respect to the sonority of the vowel in the nucleus, the possible heavy syllables in this category, i.e. the ones which are expected to attract stress, consisted in syllables with the highly sonorous vowel /a/ in the nucleus, while the light syllables consisted in syllables containing the less sonorous vowels /i/ or /u/. For example, the nonce word *Sa.nu.ri* has an HLL structure, in which the potential heavy syllable is the antepenult, *sa*, while the light syllables are expected to be the penult *su* and the final *ri*.

With respect to the position of the heavy syllable within the word, the heavy syllable could be found either in antepenultimate (HLL), penultimate (LHL) or final position (LLH). In words aimed at investigating primary stress, a heavy syllable was never found before the antepenult, since in German primary stress is restricted to the last three syllables. One category of nonce words contains two heavy syllables, one in penultimate and one in final position (LHH), of which the final syllable is always a syllable with a consonant in the coda (CVC), while in penultimate position different types of heavy syllables are tested (see table 21). This category was introduced to investigate in more detail the weight of the penultimate syllable, which might not emerge so clearly from the LHL condition (see discussion in section 6.2.2).

Not all types of heavy syllables could be investigated in all three positions because of phonotactic constraints. More specifically, a syllable with a triple onset can only be found word-initially and a syllable with two consonants in the coda can only be found word-finally in German. Furthermore, as can be seen in table (21), not all conditions contained the same number of items. This is due to the fact that in some conditions the number of items had to be reduced, since testing an equal number of items for all possible combinations of heavy syllables in each position would have resulted in an excessively high number of items, making the reading task too long for the participants and giving rise to the possibility that they might start to over-generalize the same patterns due to fatigue or boredom.

All the nonce words were constructed respecting the phonotactics of German and avoiding the resemblance to any real word, on the basis the judgement of two native German speakers who evaluated whether any nonce words might resemble existing words. The use of any existing morpheme, such as prefixes or suffixes, or any ending that might resemble any existing morpheme was also avoided. This was done in order to prevent any neighborhood effect, i.e. the possible influence of stress patterns triggered by morphemes that might be associated with a specific stress position in the real lexicon (see e.g. Sulpizio *et al.* 2013).

Furthermore, in order to avoid the possible influence of vowel sonority, in all conditions (except the one where vowel sonority was the object of investigation) vowel sonority was kept constant for most items across the vowels of the antepenultimate, penultimate and final syllable[83] so that the vowels of these syllables could only be either the low vowel /a/, the mid vowels /e/ and /o/ or the high vowels /i/ and /u/. A minority of items (29 out of 120) were not controlled for vowel sonority. This choice was due to the fact that having all items with the same vowels would have made the nonce words look extremely artificial, possibly preventing the participants from stressing the nonce word in a natural way.

Vowels with umlaut were also avoided (e.g. < ü>), since they tend to be stressed in German. Following Janßen (2003), the grapheme <e> in penultimate and final position was avoided, since it might be realized as a schwa, thus repelling stress. Orthographically complex clusters, such as <sch>, were also avoided, since they were found to attract stress by Röttger *et al.* (2012). In the case of closed syllables, the phoneme /s/ was avoided as consonant of the coda, since it might also be syllabified as the onset of the following syllables, as in the real word *Mikroskop*, which could be syllabified either as *Mi.kros.kop* or *Mi.kro.skop*.

The list of the investigated conditions and word structures for primary stress is given in (20) for 2-syllable nonce words, in (21) for 3-syllable nonce words and in (22) for 4-syllable nonce words.

Table (20). Conditions of the 2-syllable nonce words for investigating primary stress in German.

Structure	**Type of heavy syllable**	**Example**	**Number of items**
LL	[None]	Ba.fa	4
HL	Coda	Fer.po	3
LH		Fa.kaf	3

Table (21). Conditions of the 3-syllable nonce words for investigating primary stress in German.

Structure	**Type of heavy syllable**	**Example**	**Number of items**
LLL	[None]	Te.bo.to	6
HLL	Coda	Pal.sa.ra	4
LHL		Wa.tan.ka	4
LLH		Bo.go.rok	4

[83] The sonority of the vowel of the pre-antepenultimate syllable in 4-syllable nonce words was not controlled for, because stress is never expected to fall on the pre-antepenultimate, since stress in German is restricted to the last three syllables.

LLH	Double coda	Re.lo.ponk	4
HLL	Falling diphthong	Lau.fa.ka.	3
LHL		To.pau.fo	3
LLH		Bi.fu.rai	3
HLL	Vowel length	Feh.ro.fo	2
LHL		Ga.sah.ra	2
LLH		Lo.fo.reh	2
HLL	Vowel sonority	Ma.fi.ni	3
LHL		Gu.ra.pi	3
LLH		Pi.lu.na	3
HLL	Double onset	Fra.la.pa	3
LHL		Pa.kra.fa	3
LLH		Ne.po.fro	3
HLL	Triple onset	Spre.to.bo	3
LHH	Coda + coda	Me.rol.pok	3
LHH	Falling diphthong + coda	Le.rau.nof	3
LHH	Double onset + coda	Sa.tra.gal	3
LHH	Vowel length + coda	Pa.lah.ran	3

Table (22). Conditions of the 4-syllable nonce words for investigating primary stress in German.

Structure	**Type of heavy syllable**	**Example**	**Number of items**
LLLL	[None]	Me.po.ro.to	3
LHLL	Coda	Ba.lan.ka.sa	3
LLHL		Ki.fu.pun.ki	3
LLLH		Se.ro.go.pot	3
LLLH	Double coda	Di.lu.no.rast	3
LHLL	Falling diphthong	Ri.fau.li.ri	3
LLHL		Me.so.lau.po	3
LLLH		Ga.fa.na.rau	3

In the case of secondary stress, 16 nonce words were constructed, all with an XXXY(X)[84] structure, where Y represents the syllable bearing primary stress and X any type of syllable, the first or second of which could potentially receive a secondary stress. Primary stress on the right margin of the word was induced by adding real suffixes that bear primary stress, such as *-iéren* (a suffix forming verbs).

As in the case of primary stress, all nonce words were divided according to two major conditions.

The first condition consisted in words with only light syllables before primary stress, i.e. LLLY(X). This condition was aimed at investigating the directionality of secondary stress, i.e. its default position. The expectations are that, if secondary stress has a directionality from left to right, participants would collocate secondary stress on the first syllable.

The second condition consisted in nonce words with a second heavy syllable, i.e. LHLY(X) and was aimed at investigating the possible influence of syllable weight on secondary stress. The expectations are that, if secondary stress is sensitive to syllable weight, participants would place secondary stress on the second heavy syllable instead of on its default position on the first syllable. Secondary stress is never expected to be placed on the third syllable, since this would create a stress clash with primary stress on the fourth syllable, which is usually not allowed in German.

As for primary stress, nonce words were constructed in such a way to avoid any similarity with existing words and vowel sonority was kept constant between the vowels of the first two syllables, which are the ones that could receive secondary stress.

The list of the investigated conditions for secondary stress is given in (23).

Table (23). Conditions of the nonce words for investigating secondary stress in German.

Structure	**Type of heavy syllable**	**Example**	**Number of items**
LLLY(X)	[None]	Ma.la.ko.rísmus	4
LHLY(X)	Coda	Ro.den.ko.líeren	4
LHLY(X)	Falling diphthong	Ta.rau.po.lísmus	4
LHLY(X)	Double onset	Se.tro.la.níeren	4

Further 34 nonce words were also added in the experiment as fillers. These nonce words were used in order to distract the participants from the target words and to disrupt any possible prevalent pattern by varying the structures of the nonce words. The fillers, most of which had real suffixes associated with a certain stress pattern, consisted in 2-syllable nonce words, mostly with

[84] The parenthesis indicates that the final syllable after the one bearing primary stress was optional, i.e. it was present only in some items depending on the suffix used.

penultimate stress (e.g. *Döffig*), 3-syllable nonce words, mostly with antepenultimate stress (e.g. *Zahrenheit*) or with final stress (e.g. *Künerei*) and some 6-syllable nonce words (e.g. *Balafurinkorismus*). The presence of the real German suffixes in the fillers had also the purpose of inducing the participants to believe that they were overall reading a list of German words. Unlike the target nonce words, many fillers contained a vowel with umlaut, which, as in the case of the suffixes, also had the purpose of making the nonce words look more similar to German words. The complete list of fillers is given in appendix (8).

7.2.3 Procedure

The participants were asked to read aloud a list containing the nonce words. Each nonce word was inserted into the carrier sentence *Sie hat schon wieder X gesagt*, 'she said X again', where X represents the target nonce word. The use of the carrier sentence allowed to have all nonce words in the same prosodic context and it was chosen so that the target nonce word was always preceded and followed by unstressed syllables (*wíe.der* and *ge.ságt*), since a stress adjacent to the target nonce word might have created a stress clash with the possible initial or final stress of the nonce word, thus causing a stress shift to some other syllable. The items in the list were pseudo-randomized in order to avoid long sequences of nonce words with the same structure and in order to avoid repeating patterns in general. The target nonce words were mixed with the filler nonce words.

The participants were asked to read the entire list once and they were told that, in case they had difficulty reading aloud a sentence or a word, they could read it again as many times as they wanted. All the participants were recorded in a soundproof cabin at the University of Marburg. The position of stress within each nonce word was judged by ear by me. Nonce words that were mispronounced, for example by adding, deleting or swapping sounds, or that were pronounced with hesitation so that it was not possible to clearly judge the position of stress, were taken out of the final analysis.

5 of the 30 participants took part in a pilot study which had fewer items per condition (usually one item less than the final version of the experiment). The pilot study also did not contain the nonce words of the LHH type, which were added only in the final version of the experiment. For this reason, in some categories the total number of realizations of stress is not equal to the number that would be expected by multiplying the total number of items by 30 participants.

7.3 Results

The results for primary stress are given in table (24) for 2-syllable nonce words, in table (25) for 3-syllable nonce words and in table (27) for 4-syllable nonce words. The results for secondary stress are given in table (29).

All tables show for each condition the percentage and in brackets the absolute number of times that stress was collocated on a particular syllable, e.g. 52,63% (60). As expected, none of the nonce words were stressed on the pre-antepenultimate syllable, since primary stress in German is restricted to the last three syllables of a word. The total number of realizations of stress produced for each category is also given in the rightmost column. In this column, the number of realizations of stress that had to be taken out of the analysis because of mispronunciation or because of unclear stress position were included in brackets (preceded by the symbol '-') alongside the total number of realizations of stress, e.g. 176 (-4), meaning that that condition had 176 clear realizations, while 4 had to be taken out of the analysis.

Overall, out of a total of 3445 possible realizations of stress among all nonce words, 3330 were included in the final analysis, while 115 (3.33%) had to be discarded. Per each major condition, the realizations were the following: 290 (-0) for 2-syllable words, 1927 (-53) for 3-syllable nonce words, 674 (-21) for 4-syllable nonce words and 439 (-41) for the nonce words with secondary stress.

For tables (24), (25) and (27), a chi-square test was conducted between the results of each condition with a heavy syllable and those of the respective condition with only light syllables (e.g. HLL (coda) vs LLL, in the case of 3-syllable nonce words).

A condition is highlighted in dark blue if the difference with the baseline condition (highlighted in grey) is statistically highly significant ($p < 0.01$) and in lighter blue if the difference is statistically marginally significant ($0.01 \leq p < 0.05$). If a condition is not highlighted it means that the difference with the baseline condition is not statistically significant.

In the case of table (28) in which the results for 3-syllable and 4-syllable nonce words are compared with one another, and in the case of table (26), in which the results for 2-syllable and 3-syllable nonce words are compared with one another, the entire row is shaded (using the same color-coding explained above) if the difference between the 3-syllable and 4-syllable nonce words or the difference between the 2-syllable and 3-syllable nonce words is statistically significant.

Table (24). Results for the 2-syllable nonce words aimed at investigating primary stress.

Condition	**Type of heavy syllable**	**Structure**	**Example**	**Stress on P**	**Stress on F**	**Total**
1.	[None]	LL	Ba.fa	100% (120)	0% (0)	120 (-0)
2.	Coda	HL	Man.ka	100% (85)	0% (0)	85 (-0)
3.		LH	Se.lop	68.23% (58)	31.76% (27)	85 (-0)

Table (25). Results for the 3-syllable nonce words aimed at investigating primary stress.

Condition	**Type of heavy syllable**	**Structure**	**Example**	**Stress on A**	**Stress on P**	**Stress on F**	**Total**
4.	[None]	LLL	Te.bo.to	5.11% (9)	93.75% (165)	1.13% (2)	176 (-4)
5.	Coda	HLL	Pal.sa.ra	5.83% (7)	94.16% (113)	0% (0)	120 (-0)
6.		LHL	Wa.tan.ka	0.83% (1)	94.16% (113)	5% (6)	120 (-0)
7.		LLH	Bo.go.rok	28.94% (33)	18.42% (21)	52.63% (60)	114 (-1)
8.	Double coda	LLH	Re.lo.ponk	15.12% (18)	6.7% (8)	78.15% (93)	119 (-1)
9.	Falling diphthong	HLL	Lau.fa.ka	6.41% (5)	92.3% (72)	1.28% (1)	78 (-7)
10.		LHL	To.pau.fo	2.46% (2)	95.06% (77)	2.46% (2)	81 (-4)
11.		LLH	Bi.fu.rai	9.63% (8)	10.84% (9)	79.51% (66)	83 (-2)
12.	Vowel Length	HLL	Feh.ro.fo	7.27% (4)	90.90% (50)	1.81% (1)	55 (-0)
13.		LHL	Ga.sah.ra	0% (0)	96.36% (53)	3.63% (2)	55 (-0)
14.		LLH	Lo.fo.reh	12% (6)	22% (11)	66% (33)	50 (-0)
15.	Vowel sonority	HLL	Ma.fi.ni	3.40% (3)	95.45% (84)	1.13% (1)	88 (-2)
16.		LHL	Gu.ra.pi	2.24% (2)	95.50% (85)	2.24% (2)	89 (-1)
17.		LLH	Pi.lu.na	11.11% (10)	86.66% (78)	2.22% (2)	90 (-0)
18.	Double onset	HLL	Fra.la.pa	7.40% (6)	92.59% (75)	0% (0)	81 (-4)
19.		LHL	Pa.kra.fa	8.53% (7)	91.46% (75)	0% (0)	82 (-3)
20.		LLH	Ne.po.fro	10% (8)	80% (64)	10% (8)	80 (-5)
21.	Triple onset	HLL	Spre.to.bo	23.45%	76.54%	0%	81 (-4)

				(19)	(62)	(0)	
For the four conditions below (22.-25.) the reference level for statistical significance is LLH-CVC instead of LLL.							
22.	Coda + coda[85]	LHH	Me.rol.pok	17.14% (12)	27.14% (19)	55.71% (39)	70 (-5)
23.	Falling diph. + coda	LHH	Le.rau.nof	7.24% (5)	55.07% (38)	37.68% (26)	69 (-6)
24.	Double onset + coda	LHH	Sa.tra.gal	33.33% (24)	22.22% (16)	44.44% (32)	72 (-3)
25.	Vowel length + coda	LHH	Pa.lah.ran	25.67% (19)	36.48% (27)	37.83% (28)	74 (-1)

Table (26). Comparison of the results of the nonce words with 2 and 3 syllables.

	2-syllable nonce words			**3-syllable nonce words**			
Type of heavy syllable	**Structure**	**Stress on P**	**Stress on F**	**Structure**	**Stress on A**	**Stress on P**	**Stress on F**
[None]	LL	100% (120)	0% (0)	LLL	5.11% (9)	93.75% (165)	1.13% (2)
Coda	HL	100% (85)	0% (0)	LHL	0.83% (1)	94.16% (113)	5% (6)
	LH	68,23% (58)	31,76% (27)	LLH	28.94% (33)	18.42% (21)	52.63% (60)

Table (27). Results for the 4-syllable nonce words aimed at investigating primary stress.

Condition	**Type of heavy syllable**	**Structure**	**Example**	**Stress on A**	**Stress on P**	**Stress on F**	**Total**
26.	[None]	LLLL	Me.po.ro.to	4.54% (4)	95.45% (84)	0% (0)	88 (-2)
27.	Coda	LHLL	Ba.lan.ka.sa	3.37% (3)	96.62% (86)	0% (0)	89 (-1)
28.		LLHL	Ki.fu.pun.ki	0% (0)	100% (87)	0% (0)	87 (-3)
29.		LLLH	Se.ro.go.pot	1.20% (1)	40.96% (34)	57.83% (48)	83 (-2)
30.	Double coda	LLLH	Di.lu.no.rast	2.46% (2)	22.22% (18)	75.30% (61)	81 (-4)
31.	Falling diphthong	LHLL	Ri.fau.li.ri	2.43% (2)	97.56% (80)	0% (0)	82 (-3)
32.		LLHL	Me.so.lau.po	0% (0)	100% (83)	0% (0)	83 (-2)
33.		LLLH	Ga.fa.na.rau	1.23% (1)	17.28% (14)	81.48% (66)	81 (-4)

[85] As explained in sub-chapter (x), the results of conditions with two heavy syllables (LHH), 22.-25., are compared through a chi-square test with the LLH condition with a final syllable with a consonant in the coda (CVC), 7., instead of with the LLL condition.

Table (28). Comparison of the results of the nonce words with 3 and 4 syllables.

	3-syllable nonce words				**4-syllable nonce words**			
Type of H	**Struct.**	**Stress on A**	**Stress on P**	**Stress on F**	**Struct.**	**Stress on A**	**Stress on P**	**Stress on F**
[None]	LLL	5.11% (9)	93.75% (165)	1.13% (2)	LLLL	4.54% (4)	95.45% (84)	0% (0)
Coda	HLL	5.83% (7)	94.16% (113)	0% (0)	LHLL	3.37% (3)	96.62% (86)	0% (0)
	LHL	0.83% (1)	94.16% (113)	5% (6)	LLHL	0% (0)	100% (87)	0% (0)
	LLH	28.94% (33)	18.42% (21)	52.63% (60)	LLLH	1.20% (1)	40.96% (34)	57.83% (48)
Double coda	LLH	15.12% (18)	6.7% (8)	78.15% (93)	LLLH	2.46% (2)	22.22% (18)	75.30% (61)
Falling diphth.	HLL	6.41% (5)	92.3% (72)	1.28% (1)	LHLL	2.43% (2)	97.56% (80)	0% (0)
	LHL	2.46% (2)	95.06% (77)	2.46% (2)	LLHL	0% (0)	100% (83)	0% (0)
	LLH	9.63% (8)	10.84% (9)	79.51% (66)	LLLH	1.23% (1)	17.28% (14)	81.48% (66)

Table (29). Results for the nonce words aimed at investigating secondary stress.

	Type of heavy syllable	**Structure**	**Example**	**Stress on 1° σ**	**Stress on 2° σ**	**Total**
34.	[None]	LLLY(X)	Ma.la.ko.rísmus	80.34% (94)	19.6% (23)	117 (-3)
35.	Coda	LHLY(X)	Ro.den.ko.líeren	44.95% (49)	55.04% (60)	109 (-11)
36.	Falling diphthong	LHLY(X)	Ta.rau.po.lísmus	18.51% (20)	81.48% (88)	108 (-12)
37.	Double onset	LHLY(X)	Se.tro.la.níeren	81.90% (86)	18.09% (19)	105 (-15)

7.4 Discussion of results

The results concerning the 3-syllable nonce words (table 25) will be discussed first, since these are the type of nonce words that allow the full range of the possible positions of stress, which in German is bound to the last three syllables. Subsequently, the results concerning the 2-syllable nonce words will be discussed and finally the results concerning the 4-syllable nonce words.

In order to facilitate the reference to a specific condition, a formula of the type [word structure]-[type of heavy syllable] will sometimes be used, such as LLH-CVC, where LLH represents the word structure indicating the position of the heavy syllable, i.e. in this example in final position, and CVC indicates the type of heavy syllables, i.e. in this example a syllable with a consonant in the coda.

7.4.1 Discussion of results of the 3-syllable nonce words

For ease of reference, table (25) containing the results of the 3-syllable nonce words is reported again below.

Table (25). Results for the 3-syllable nonce words aimed at investigating primary stress.

Condition	Type of heavy syllable	Structure	Example	Stress on A	Stress on P	Stress on F	Total
4.	[None]	LLL	Te.bo.to	5.11% (9)	93.75% (165)	1.13% (2)	176 (-4)
5.	Coda	HLL	Pal.sa.ra	5.83% (7)	94.16% (113)	0% (0)	120 (-0)
6.		LHL	Wa.tan.ka	0.83% (1)	94.16% (113)	5% (6)	120 (-0)
7.		LLH	Bo.go.rok	28.94% (33)	18.42% (21)	52.63% (60)	114 (-1)
8.	Double coda	LLH	Re.lo.ponk	15.12% (18)	6.7% (8)	78.15% (93)	119 (-1)
9.	Falling diphthong	HLL	Lau.fa.ka	6.41% (5)	92.3% (72)	1.28% (1)	78 (-7)
10.		LHL	To.pau.fo	2.46% (2)	95.06% (77)	2.46% (2)	81 (-4)
11.		LLH	Bi.fu.rai	9.63% (8)	10.84% (9)	79.51% (66)	83 (-2)
12.	Vowel Length	HLL	Feh.ro.fo	7.27% (4)	90.90% (50)	1.81% (1)	55 (-0)
13.		LHL	Ga.sah.ra	0% (0)	96.36% (53)	3.63% (2)	55 (-0)
14.		LLH	Lo.fo.reh	12% (6)	22% (11)	66% (33)	50 (-0)
15.	Vowel sonority	HLL	Ma.fi.ni	3.40% (3)	95.45% (84)	1.13% (1)	88 (-2)
16.		LHL	Gu.ra.pi	2.24% (2)	95.50% (85)	2.24% (2)	89 (-1)
17.		LLH	Pi.lu.na	11.11% (10)	86.66% (78)	2.22% (2)	90 (-0)
18.	Double onset	HLL	Fra.la.pa	7.40% (6)	92.59% (75)	0% (0)	81 (-4)
19.		LHL	Pa.kra.fa	8.53% (7)	91.46% (75)	0% (0)	82 (-3)
20.		LLH	Ne.po.fro	10% (8)	80% (64)	10% (8)	80 (-5)

21.	Triple onset	HLL	Spre.to.bo	23.45% (19)	76.54% (62)	0% (0)	81 (-4)
For the 4 conditions below (22.-25.) the reference level for statistical significance is LLH-CVC instead of LLL.							
22.	Coda + coda[86]	LHH	Me.rol.pok	17.14% (12)	27.14% (19)	55.71% (39)	70 (-5)
23.	Falling diph. + coda	LHH	Le.rau.nof	7.24% (5)	55.07% (38)	37.68% (26)	69 (-6)
24.	Double onset + coda	LHH	Sa.tra.gal	33.33% (24)	22.22% (16)	44.44% (32)	72 (-3)
25.	Vowel length + coda	LHH	Pa.lah.ran	25.67% (19)	36.48% (27)	37.83% (28)	74 (-1)

As can be seen from table (25), with respect to the condition with only light syllables (CV), LLL (condition 4.), the results show that stress falls overwhelmingly on the penultimate syllable (93.75%), confirming the default position of primary stress on the penultimate syllable in German.

With respect to the three conditions with a heavy syllable with a consonant in the coda (CVC), (5-7.), if the heavy syllable is in antepenultimate position (HLL, 5.), the heavy syllable does not seem to attract stress, since stress still falls mostly on the penult, as in the LLL condition (94.16%).

If the heavy syllable is in penultimate position (LHL, 6.), the percentage of stress on the penult is 94.16% and the results of the chi-square test indicate that the distribution of stress in LHL is statistically significantly different (although only marginally) from that of the LLL condition, which has 93.75% of stress on the penult. Nonetheless, the statistically significant difference between the distributions of stress in LLL and LHL might be due to the fact that in LLL there is a 5.11% of stress on the antepenult, while in LHL there is a 5% of stress on the final rather than from the increase of stress itself on the penult. On the basis of these results, it is thus difficult to assess whether the penultimate syllable in LHL actually attracts stress, although this was found to be the case by Janßen (2003), in whose experiment the difference between the percentage of stress on the penult in LLL and LHL nonce words was significant.

If the heavy syllable is in final position (LLH, 7.), the percentage of stress on the final increases to 52.63% with respect to LLL (1.13% of stress on the final) and the increase is statistically highly significant. In LLH, stress also falls to a great extent on the antepenult (28.94%), while stress on the penult drops to 18.42%. These results strongly point to an influence of a final syllable with a consonant in the coda (CVC), leading to the formation of a moraic trochee on the

[86] As explained in sub-chapter (x), the results of conditions with two heavy syllables (LHH), 22.-25., are compared through a chi-square test with the LLH condition with a final syllable with a consonant in the coda (CVC), 7., instead of with the LLL condition.

final syllable, LL(H́), although the results also suggest that stress can often fall on the antepenult, leading to the formation of a disyllabic moraic trochee (ĹL)H. These results are in line with those of Janßen (2003) and Röttger *et al.* (2012), since both found that in LLH stress falls either on the antepenult or final, however they differ in the fact that in both Janßen (2003) and Röttger *et al.* (2012) stress fell mostly on the antepenult, although, at least in Janßen (2003), the difference between the percentage of stress on the antepenult and the final was not statistically significant.

With respect to the condition with a heavy syllable with two consonants in the coda (CVCC), found only in final position (LLH, 8.), the results indicate a very clear influence of the final heavy syllable, which was stressed 78.15% of the time, in comparison to 1.13% of stress on the final syllable in the LLL condition and the difference is statistically highly significant. Furthermore, the percentage of stress on the final syllable in this condition with two consonants in the coda increases considerably with respect to the percentage of stress in the condition with the final syllable with one consonant in the coda (LLH-CVC, 7.), namely 78.15% in the former *vs* 52.63% in the latter and the results of a chi-square test indicate that the difference is statistically highly significant ($p < 0.001$). This suggests that a final syllable with two consonants in the coda (CVCC) should be considered a superheavy syllable in German, i.e. a syllable which attracts stress significantly more often than a heavy syllable. These results are in line with what was found in Janßen (2003), although the author tested different word structures, namely CVC.CV.CVCC and CV.CVC.CVCC. These results are, however, not in line with what was found in Röttger *et al.* (2012), in whose study, in a CV.CV.CVCC nonce word, stress fell more often on the final than in a CV.CV.CVC nonce word, but the difference was not statistically significant.

With respect to the three conditions with a heavy syllable with a falling diphthong (CVG), (9.-11.), it is possible to see that if the syllable with a diphthong is in antepenultimate or penultimate position (HLL, 9. or LHL, 10.), stress still falls mostly on the penult (92.3% and 95.06% of the times respectively), like in the LLL condition and the difference with respect to LLL is not statistically significant, suggesting that in neither antepenultimate nor in penultimate position a syllable with a falling diphthong attracts stress. However, if a syllable with a falling diphthong is in final position (LLH, 11.), it clearly attracts stress (79.51%) and the difference with respect to the LLL condition is statistically highly significant. Furthermore, when comparing the percentage of final stress of the CV.CV.CVC condition (7.) with the one of the CV.CV.CVG condition (11.), 52.63% and 79.51% respectively, the difference turns out to be statistically significant ($p < .001$), suggesting that, in final position, a syllable with a falling diphthong (CVG) attracts stress considerably more often than a syllable with a consonant in the coda (CVC). On this basis, it is possible to say that a final syllable with a falling diphthong forms in German a superheavy syllable, exactly like a syllable with two consonants in the coda (CVCC). These results contrast with those of Röttger *et al.* (2012), in which in CV.CV.CVG nonce words the final syllable was stressed more often than in a CV.CV.CVC nonce word but the difference was not statistically significant.[87]

With respect to the three conditions with a heavy syllable with a long vowel (CVV, 12.-14.), it is possible to see that if the syllable with a long vowel is in antepenultimate or penultimate position (HLL, 12. or LHL, 13.), stress still falls mostly on the penult (90.90% and 96.36% of the times respectively), like in the LLL condition and the difference with LLL is not statistically significant, suggesting that in neither the antepenultimate nor in the penultimate position a syllable with a long vowel attracts stress. However, if the syllable with a long vowel is in final position (LLH, 14.) it attracts stress 66% of the times and the difference with respect to the LLL condition is statistically highly significant. When comparing the condition with a syllable with a long vowel in final position and the condition with a syllable with a consonant in the coda in final position (i.e. CV.CV.CVV *vs* CV.CV.CVC, 52.63% of final stress in the former *vs* 66% of final stress in the latter) the difference is not statistically significant ($p = 0.06$), suggesting that, in final position, a syllable with a long vowel counts as heavy as a syllable with a consonant in the coda.

With respect to the three conditions with a heavy syllable containing the highly sonorous vowel /a/ (15.-17.), it is possible to see that, irrespective of whether the syllable containing the highly sonorous vowel /a/ is in antepenultimate, penultimate or final position (HLL, 15., LHL, 16., or LLH, 17.), stress still falls predominantly on the penultimate syllable (95.45%, 95.50% and 86.66% of the times respectively) and the difference with respect to the LLL condition is not statistically significant for any of the three conditions, suggesting that vowel sonority, at least with respect to the contrast /a/ *vs* /i/-/u/ that was tested in this experiment, does not play a role in primary stress assignment in German.

With respect to the three conditions with a heavy syllable with a double onset (CCV, 18.-20), it is possible to see that, if the syllable with a double onset is in antepenultimate or penultimate position (HLL, 18. or LHL, 19.), stress still falls mostly on the penult (92.59% and 91.46% of the times respectively) like in the LLL condition and the difference with LLL is not statistically significant, suggesting that neither in antepenultimate nor in penultimate position a syllable with a double onset attracts stress. However, if the syllable with a double onset is in final position (LLH, 20.), stress still falls mostly on the penult, but the percentage of stress on the penult drops to 80% in comparison to the LLL condition (93.75%) and the difference between the two conditions turns out

[87] Also in Janßen (2003) final falling diphthongs were tested in a small pilot study. However, unlike in the current study, the syllables with a diphthong also contained a consonant in the coda (CVGC) and they were tested in word types different from the one tested here. Janßen's data still show at least a numerical increase of stress on the CVGC final syllable with respect to the CVC final syllable.

to be statistically highly significant. In the LLH condition, stress is placed 10% of the times on the antepenult and 10% of the times on the final. This tendency to place stress to a certain degree also on the antepenult when the final is heavy was also found in the conditions with a final syllable with one or two consonants in the coda (LLH-CVC and LLH-CVCC) (but less in the other conditions with a final heavy or superheavy syllable) and could be ascribed to the tendency to build a trochaic foot either at the left or right margin of the word. In any case, in the condition with a double onset in final position (LLH-CCV), on the basis of the fact that the final syllable attracts stress only 10% of the times, this type of syllable cannot really considered to be a heavy syllable. Rather, the behavior of the final syllable with a double onset can be attributed to the only limited influence on stress typical of complex onsets, according to which complex onsets tend to attract stress only to a limited extent, and usually as a function of the number of segments in the onset (e.g. Ryan 2014 for English). This gradient behavior of the onset was also found in German by Röttger *et al.* (2012) comparing V.CVC, CV.CVC, CCV.CVC and CCCV.CVC nonce words, in which the percentage of stress on the first syllable increased as a function of the segments in the onset.

With respect to the condition with a heavy syllable with a triple onset (CCCV), found only in the antepenultimate syllable (HLL, 21.), the results, as for the syllable with a double onset in final position, apparently tend to suggest that a syllable with a triple onset in antepenultimate position attracts stress, although only to a limited extent (23.45% of stress on the antepenult), since the difference with the LLL condition (5.11% of stress on the antepenult) is statistically highly significant. However, the condition with a triple onset contained only 3 items, one of which received stress on the antepenult considerably more often than the other two. Namely, *Strafala* and *Spretobo* were stressed on the antepenult 3/27 and 4/29 of the times, while *Skribuli* was stressed on the antepenult 12/25 of the times. Taking out of the analysis the anomalous item *Skribuli*, the distribution of stress for the CCCV.CV.CV condition becomes 12.5% of stress on the antepenult, 87.5% of stress on the penult and 0% on the final. These percentages are similar to those of the LLL condition and the difference between the two does not turn out to be statistically significant ($p = 0.12$). In light of this correction to the data, a triple onset in antepenultimate position does not seem to attract stress. However, the (only numerical) increase of the percentage of stress on the antepenult with respect to the LLL condition (12.5% *vs* 5.11% of stress on the antepenult respectively) might also be alternatively interpreted as an effect of the gradual influence typical of complex onsets, although these data are not sufficient to confirm this hypothesis.

Within the 3-syllable nonce words, the remaining four conditions tested (22.-25.) are those containing two heavy syllables, one in penultimate position and one in final position (LHH). Each of these conditions is compared with the LLH condition with a final syllable with a consonant in the coda (CV.CV.CVC, 7.), instead of with the LLL condition (4.). As explained in the sub-chapter (7.2.2) above, conditions 22.-25. are aimed at investigating more in detail the role of a heavy syllable in penultimate position. More specifically, the syllable in penultimate position is the target syllable, while the syllable in final position is always a syllable with a consonant in the coda (CVC), so each LHH condition has an L.H.CVC structure. In order to see whether the heavy penult attracts stress, each LHH condition is compared with the LLH condition with a final syllable with a consonant in the coda (CV.CV.CVC). Since in the CV.CV.CVC condition stress falls mostly on the final, if in an LHH nonce word the heavy penult attracts stress, we expect a shift to the penult compared to the LLH condition.

Looking at the results of the LHH condition with a penultimate syllable with a consonant in the coda (CV.CVC.CVC, 22.) it is possible to see that the percentage of stress on the final is 55.71%, which is comparable to the percentage of stress on the final of the LLH condition (7.) (52.63%). However, in the LHH condition stress on the penult increases to 27.14% with respect to the 18.42% of stress on the penult of the LLH condition. In spite of this numerical increase, the difference between the results of LHH and LLH is not statistically significant, so that it cannot be concluded that a penultimate syllable with a consonant in the coda attracts stress in this type of nonce word.

With respect to the LHH condition with a penultimate syllable with a falling diphthong (CV.CVG.CVC, 23.), when comparing the distribution of stress with the LLH condition (7.), it is possible to see that the percentage of stress on the penult increases considerably, from 18.42% of LLH to 55.07% of LHH, and the difference is statistically highly significant, suggesting that a diphthong in penultimate position attracts stress, at least in an LHH nonce word with a final syllable with a consonant in the coda.

With respect to the LHH condition with a penultimate syllable with a double onset (CV.CCV.CVC, 24.), it is possible to see that stress falls mostly on the final and antepenult, as in the LLH condition (7.), and even if there is a slight increase of stress on the penult with respect to LLH (22.22% *vs* 18.42% respectively) the difference is not statistically significant, suggesting that a double onset in penultimate position in an LHH nonce word does not attract stress, or does so only slightly.

With respect to the LHH condition with a penultimate syllable with a long vowel (CV.CVV.CVC, 25.), when comparing the distribution of stress with LLH (7.) it is possible to note a considerable increase of stress on the penult, from 18.42% of LLH to 36.48% in LHH, and the difference is statistically significant, suggesting that a syllable with a long vowel in penultimate position in an LHH nonce word attracts stress.

The results of the LHH conditions suggest that some of the same structures that clearly attract stress in final position in a LLH nonce word also attract stress in penultimate position in LHH, namely a syllable with a falling diphthong (23.) and a syllable with a long vowel (25.). It is somewhat unexpected that also a penultimate syllable with a consonant in the coda (22.) does not attract stress in LHH, since in LLH this type of syllable patterns like a syllable with a long vowel, so that the two syllable structures might also be expected to pattern together in penultimate position in LHH. When comparing CV.CVV.CVC (25.) with LLH-CVC (7.), the difference was statistically significant but not in a strong way (p = 0.01). Thus, it might perhaps be the case that with more data also the difference between CV.CVC.CVC (22.) with LLH-CVC (7.) turns out to be statistically significant. An alternative explanation for these results might also be that, in a potential hierarchy of heavy syllables, both a heavy syllable with a diphthong and a heavy syllable with a long vowel are ranked higher than a heavy syllable with a consonant in the coda, so that when each of these three types of heavy syllable 'competes' with a CVC syllable in final position (as in the LHH items), the weight of the final CVC overrides that of the a penultimate CVC but not that of the penultimate CVG and CVV, which are higher up in the hierarchy. However, although a higher ranking for both CVG and CVV with respect to CVC might be explained by the fact that both types of syllables could be considered more sonorous than CVC, the data from the results of the LLH nonce words suggest that in German CVV patterns more similarly to CVC than CVG.

With respect to the results of the four LHH conditions, another aspect to highlight is that a syllable with a falling diphthong (CVG, 23.) and a syllable with a long vowel (CVV, 25.) in penultimate position in LHH pattern like their equivalent in LLH (11. and 14.), in the sense that also in LHH a syllable with a falling diphthong attracts significantly more often than a syllable with a long vowel, since the difference between the two distributions in LHH (23. *vs* 25.) is statistically significant (p = .007).

Overall, the results of the 3-syllable nonce words suggest that the syllable which plays the major role with respect to stress assignment in German is the final syllable, in accordance with previous studies. More specifically, both a final syllable with a consonant in the coda (CVC) and a final syllable with a long vowel (CVV) attract stress and thus count as heavy syllables. Furthermore, both a final syllable with two consonants in the coda (CVCC) and a final syllable with a falling diphthong (CVG) attract stress significantly more often than a final syllable with a consonant in the coda and a final syllable with a long vowel, thus forming superheavy syllables. Also, a final syllable with a double onset (CCV) seems to shift the percentage of stress towards the antepenult and the final, although only slightly.

With respect to the influence of the penult, the LHH structures reveal that a penultimate syllable with a long vowel (CVV) attracts stress, but not a penultimate syllable with a consonant in the coda (CVC), and a penultimate syllable with a falling diphthong (CVG) attracts stress more often than a penultimate syllable with a long vowel. The LHL conditions overall did not yield any meaningful results with respect to the possible influence of a heavy penult, confirming that if the final syllable is light, stress tends to go on the penult by default, as found by Janßen (2003).

A heavy antepenult in HLL does not seem to attract stress, again confirming the results found in Janßen (2003), according to which, if the final syllable is light, stress tends to fall on the penult irrespective of the structure of the other syllables.

7.4.2 Discussion of results of the 2-syllable nonce words

I will now turn to discuss the results of the 2-syllable nonce words, reported in table (24).

As explained in sub-chapter (7.2.2), 2-syllable words have been added to the experiment in order to see the possible influence of a heavy syllable in penultimate or final position without the effect of parsing that might emerge in 3-syllable words.

For ease of reference, table (24) containing the results of the 2-syllable nonce words is reported again below, as well as table (26), containing the comparison of the results between nonce words of 2 syllables and nonce words of 3 syllables.

Table (24). Results for the 2-syllable nonce words aimed at investigating primary stress.

Condition	**Type of heavy syllable**	**Structure**	**Example**	**Stress on P**	**Stress on F**	**Total**
1.	[None]	LL	Ba.fa	100% (120)	0% (0)	120 (-0)
2.	Coda	HL	Man.ka	100% (85)	0% (0)	85 (-0)
3.		LH	Se.lop	68.23% (58)	31.76% (27)	85 (-0)

Table (26). Comparison of the results of the nonce words with 2 and 3 syllables.

	2-syllable nonce words			**3-syllable nonce words**			
Type of heavy syllable	**Structure**	**Stress on P**	**Stress on F**	**Structure**	**Stress on A**	**Stress on P**	**Stress on F**
[None]	LL	100% (120)	0% (0)	LLL	5.11% (9)	93.75% (165)	1.13% (2)
Coda	HL	100% (85)	0% (0)	LHL	0.83% (1)	94.16% (113)	5% (6)

	LH	68.23% (58)	31.76% (27)	LLH	28.94% (33)	18.42% (21)	52.63% (60)

Looking at the condition with only light syllables, LL (1.) it is possible to observe that stress falls 100% of the times on the penult, confirming the default position of stress on the penult in German and the tendency to fully parse the word in a trochaic foot (ĹL), while there is no variation as in the LLL condition (4.), in which stress also falls mostly on the penult, but also on the antepenult and on the final. These results also confirm the avoidance of the formation of a degenerate foot on the final syllable, as in *L(Ĺ), a foot type which is usually not allowed in German.

Also in the condition with a penultimate syllable with a consonant in the coda, HL, (2.), stress falls 100% of the times on the penult. The lack of difference with the LL condition does not allow to ascribe the percentage of stress on the penult to the presence of the heavy syllable, so that it is likely that also in this condition the penult is stressed because it represents the default position for stress.

With respect to the condition with a final syllable with a consonant in the coda, LH (3.), the expectations for this condition were that, if the final heavy syllable attracts stress, the final syllable would be stressed most of the times, while stress would fall on the penult only a minority of the times. Furthermore, the expectations were also that the final syllable in LH would receive more often stress than the final syllable in LLH, since in the latter stress tends also to fall on the antepenult and on the penult. However, the above expectations were not borne out, since in LH stress falls mostly on the penultimate syllable, with 68.23% on the penult and 31.76% on the final. Nonetheless, the fact the there is a statistically significant shift of stress towards the final with respect to the LL condition suggests that the final still exerts an influence, as was found to be the case for a final syllable with a consonant in the coda in the 3-syllable nonce words (LLH). One explanation why stress tends to stay on the penult even if the final is heavy might be that speakers, when confronted with 2-syllable words, might tend to parse the entire word into a disyllabic foot and leave no syllable unparsed, thus following a tendency to achieve full parsing even at the cost of overriding syllable weight (see also the discussion of 4-syllable nonce words). However, apart from the case of (ĹL), this would imply the formation of some very marked foot structures, such as (H́L) and (ĹH), so that some speakers still choose to stress the heavy final and to form a bimoraic trochee, leaving a syllable unparsed, as in L(H́).

7.4.3 Discussion of results of the 4-syllable nonce words

For ease of reference, table (27) containing the results of the 4-syllable nonce words is reported again below, as well as table (28), containing the comparison of the results between nonce words of 3 syllables and nonce words of 4 syllables.

Table (27). Results for the 4-syllable nonce words aimed at investigating primary stress

Condition	**Type of heavy syllable**	**Structure**	**Example**	**Stress on A**	**Stress on P**	**Stress on F**	**Total**
26.	[None]	LLLL	Me.po.ro.to	4.54% (4)	95.45% (84)	0% (0)	88 (-2)
27.	Coda	LHLL	Ba.lan.ka.sa	3.37% (3)	96.62% (86)	0% (0)	89 (-1)
28.		LLHL	Ki.fu.pun.ki	0% (0)	100% (87)	0% (0)	87 (-3)
29.		LLLH	Se.ro.go.pot	1.20% (1)	40.96% (34)	57.83% (48)	83 (-2)
30.	Double coda	LLLH	Di.lu.no.rast	2.46% (2)	22.22% (18)	75.30% (61)	81 (-4)
31.	Falling diphthong	LHLL	Ri.fau.li.ri	2.43% (2)	97.56% (80)	0% (0)	82 (-3)
32.		LLHL	Me.so.lau.po	0% (0)	100% (83)	0% (0)	83 (-2)
33.		LLLH	Ga.fa.na.rau	1.23% (1)	17.28% (14)	81.48% (66)	81 (-4)

Table (28). Comparison of the results of the nonce words with 3 and 4 syllables.

	3-syllable nonce words				**4-syllable nonce words**			
Type of H	**Struct.**	**Stress on A**	**Stress on P**	**Stress on F**	**Struct.**	**Stress on A**	**Stress on P**	**Stress on F**
[None]	LLL	5.11% (9)	93.75% (165)	1.13% (2)	LLLL	4.54% (4)	95.45% (84)	0% (0)
Coda	HLL	5.83% (7)	94.16% (113)	0% (0)	LHLL	3.37% (3)	96.62% (86)	0% (0)
	LHL	0.83% (1)	94.16% (113)	5% (6)	LLHL	0% (0)	100% (87)	0% (0)
	LLH	28.94% (33)	18.42% (21)	52.63% (60)	LLLH	1.20% (1)	40.96% (34)	57.83% (48)
Double coda	LLH	15.12% (18)	6.7% (8)	78.15% (93)	LLLH	2.46% (2)	22.22% (18)	75.30% (61)
Falling diphth.	HLL	6.41% (5)	92.3% (72)	1.28% (1)	LHLL	2.43% (2)	97.56% (80)	0% (0)
	LHL	2.46% (2)	95.06% (77)	2.46% (2)	LLHL	0% (0)	100% (83)	0% (0)

	LLH	9.63% (8)	10.84% (9)	79.51% (66)	LLLH	1.23% (1)	17.28% (14)	81.48% (66)

The last category of nonce words that has been investigated with respect to primary stress consists in the 4-syllable nonce words, whose results are reported in table (27). These nonce words were added to the experiment in order to investigate more in detail the possible influence on stress assignment of full parsing into trochaic feet, which is possible in 4-syllable nonce words but usually not in 3-syllable nonce words.

Looking at the condition with no heavy syllables, LLLL (26.), i.e. the baseline condition with which all the others are compared, one can see that stress falls mostly on the penult, confirming the default position of primary stress on the penultimate syllable also in 4-syllable words.

With respect to the condition with an antepenultimate syllable with a consonant in the coda, (LHLL-CVC, 27.), stress falls mostly on the penult and the difference with the LLLL condition is not significant, suggesting no influence of a heavy antepenult.

With respect to the condition with a penultimate syllable with a consonant in the coda (LLHL-CVC, 28.), stress on the penult increases with respect to LLLL (from 95.45% to 100%) and the difference is statistically significant (although not highly) suggesting an influence of a heavy penult, as seemed to be the case also for the corresponding LHL (6.) condition with respect to LLL (4.).

With respect to the condition with a final syllable with a consonant in the coda, (LLLH-CVC, 29.), there is a clear shift of stress from the penult to the final in comparison to LLLL, since the final is stressed 57.83% of the times in the former and 0% in the latter and the difference is statistically highly significant, confirming the influence of a final syllable with a consonant in the coda, as was the case in LLH (7.).

With respect to the condition with a final syllable with two consonants in the coda, (LLLH-CVCC), (30.), it is possible to see that the final syllable clearly attracts stress, since it is stressed 75.30% of the times in comparison to 0% of the times on the final in LLLL. Furthermore, the difference between the distribution of stress in LLLH with a final syllable with a consonant in the coda (CVC, 29.) and LLLH with a final syllable with two consonants in the coda (CVCC, 29.) is statistically significant ($p = 0.03$), suggesting that a final syllable with two consonants in the coda counts as a superheavy syllable, as was found to be the case also in the corresponding 3-syllable nonce words.

With respect to the condition with an antepenultimate syllable with a falling diphthong, (LHLL-CVG, 31.), stress falls mostly on the penult and the difference with the LLLL condition is not significant, suggesting no influence of a heavy antepenult.

With respect to the condition with a penultimate syllable with a falling diphthong (LLHL-CVG, 32.), stress on the penult increases slightly with respect to the LLLL condition (from 95.45% to 100%) and the difference is statistically significant (although not highly), suggesting an influence of a syllable with a falling diphthong in penultimate position, as was found to be the case also in the 4-syllable nonce words with a penultimate syllable with a consonant in the coda (LLHL-CVC, 28.). However, the same results were not found in the corresponding 3-syllable nonce words with a penultimate syllable with a falling diphthong (10.), in which the heavy penult was not found to attract stress in a significant way.

With respect to the condition with a final syllable with a falling diphthong, (LLLH-CVG, 33.), the results show a clear shift of stress towards the final syllable with respect to the LLLL condition (from 0% to 81.48% in LLLH), indicating a clear influence of a final syllable with a falling diphthong. Furthermore, the difference with respect to the LLLH with a final syllable with a consonant in the coda (CVC, 29.), in which the final attracted stress 57.83% of the times, was found to be statistically significant ($p = 0.004$) suggesting that a final syllable with a falling diphthong attracts more often than a final syllable with a consonant in the coda and should thus count as a superheavy syllable.

Overall, the results of the 4-syllable nonce words mirror precisely those of the same conditions in the 3-syllable nonce words, in that a final syllable with a consonant in the coda (CVC) attracts stress and a final syllable with two consonants in the coda (CVCC) or a falling diphthong (CVG) attract stress even more often, thus forming superheavy syllables. The results of the 4-syllable nonce words also match those of the 3-syllable nonce words in that a heavy antepenult never attracts stress, and a penult with a consonant in the coda attracts stress. The only mismatch was found in that in the LLHL nonce words with a falling diphthong, in which the penult seems to attract stress but this was not the case in the LHL nonce words with a falling diphthong.

On the basis of these results, it might look like the possibility to achieve full parsing in 4-syllable words does not play a role, since 3-syllable and 4-syllable words tend to behave similarly with respect to the distribution of stress. However, when directly comparing the percentage of stress of each category of the 3-syllable words with the corresponding category of the 4-syllable words (table 28), some specific patterns seem to emerge.

More specifically, when comparing LLL with LLLL stress equally falls predominantly on the penult and the difference is not statistically significant, suggesting no effect of full parsing in LLLL, which would have implied a higher percentage of stress on the penult with respect to LLL, forming two trochaic feet as in (L̀L)(ĹL).

The same results emerge when comparing HLL with LHLL and LHL with LLHL, either with a syllable with a consonant in the coda (CVC) or with a falling diphthong (CVG): in all cases stress is predominantly on the penult and the difference between the various conditions is not statistically significant, suggesting no effect of parsing.

However, when comparing LLH with LLLH in all the three conditions that were tested, i.e. when the final heavy syllable has a consonant in the coda (CVC), two consonants in the coda (CVCC) or a falling diphthong (CVG), it seems that stress on the penult increases in LLLH with respect to LLH and the difference is always statistically significant in all three cases. Namely, in the conditions with a syllable with a consonant in the coda (CVC) stress on the penult increases from 18.42% in LLH to 40.96% in LLLH. In the conditions with two consonants in the coda (CVCC) stress on the penult increases from 6.7% in LLH to 22.22% in LLLH. In the conditions with a falling diphthong (CVG) stress on the penult increases from 10.84% in LLH to 17.28% in LLLH. In all these cases of 4-syllable nonce words there seems to be a higher tendency to place stress on the penult with respect to the corresponding 3-syllable nonce words, thus achieving a full parsing of the type (L̀L)(ĹH).

Interestingly, it can be concluded that this effect of full parsing in 4-syllable nonce words seems to emerge only in those nonce word types that show a strong sensitivity to syllable weight (in this case, nonce words with a heavy final). On the other hand, there does not seem to be a contrast between the tendency to stress the heavy (or superheavy) final syllable and the tendency to place stress on the penult in order to achieve full parsing, since the increase on the penult in the LLLH nonce words with respect to LLH nonce words takes place at the cost of decreasing stress on the antepenult and not on the final heavy syllable. For instance, in the case of the condition with a final syllable with a consonant in the coda (CVC), the distribution of stress for LLH is 28.94% on the antepenult, 18.42% on the penult, 52.63% on the final, while for LLLH is 1.20% on the antepenult 40.96% on the penult, 57.83% on the final. As can be seen, in both conditions stress remains on the final around 50% of the times, while stress on the penult increases as stress on the antepenult decreases.

The fact that the effect of parsing in 4-syllable nonce words seems to emerge only in conditions with a heavy or superheavy final syllable (i.e. when comparing LLH with LLLH) might perhaps be due to the fact that in all the other conditions in 3-syllable nonce words (HLL and LHL) stress is already overwhelmingly on the penult so that effect of parsing in their corresponding 4-syllable nonce words (LHLL and LLHL), even if present, cannot be detected clearly. On the contrary, in the conditions in which stress is also considerably placed on the antepenult (none in our results) or on the final (in LLH), a stress shift to the penult in their respective 4-syllable nonce words due to the effect of parsing becomes possible and more clearly visible.

Overall, it can be concluded that, on the one hand, 4-syllable words behave like 3-syllable words with respect to the default position of stress and the types of syllables which count as heavy, with a final syllable with a consonant in the coda (CVC) counting as heavy and a final syllable with two consonants in the coda (CVCC) or with a falling diphthong (CVG) counting as superheavy. A penultimate syllable with a consonant in the coda (CVC) seems also to count as heavy and possibly also a penultimate syllable with a falling diphthong (CVG). On the other hand, an effect of full parsing, i.e. placing stress on the penult more often than in the 3-syllable words, seems to emerge only in the conditions with a final heavy or superheavy syllable, i.e. those conditions in which stress is not predominantly on the penult.

Finally, some considerations concerning individual variation among the participants with respect to the placement of primary stress will be provided.

The results of a mixed-effects logistic regression analysis indicated no effect of sex ($p = 0.295$), age ($p = 0.674$) or region[88] with respect to the tendency to place stress mostly on the antepenult, penult or final.

However, with respect to the role of individual variation, looking at the results it is possible to note that, although participants overall behave similarly to one another, some individual variation is still found in specific cases.

More specifically, throughout all the conditions of the experiment, stress was collocated mostly on penult by all participants. On average, stress was placed 7.3 times on the antepenult, 68.9 times on the penult and 20.4 times on the final. The high number of stress on the penult was due to the fact that the experiment contained many conditions that triggered overwhelmingly stress on the penult (e.g. all the conditions with a final open syllable, such as HLL or LHL). Among the participants, the percentage of stress on the penult almost always remained close to the mean of 68.9 times, with most participants stressing the penult between 57 and 82 times, while one speaker stressed the penult considerably more often than average, i.e. 90 times.

More variation was present concerning the choice of whether stressing the antepenult or the final. With respect to the accentuation of the antepenult, the participants might be divided into two groups, one comprising the majority of participants (24) stressing the antepenult between 0 and 11 times and the other comprising 6 participants, who stressed the antepenult considerably more often, i.e. 16, 17, 20, 26 and 30 times each.

[88] For the p-values concerning single regions see appendix (x).

With respect to the accentuation of the final syllable, the participants showed the highest level of variability, with 14 participants stressing the final between 9 and 19 times, 8 participants stressing the final between 21 and 26 times and 6 participants stressing the final between 30 and 35 times.

These results suggest that there is certain degree of individual variability specifically linked to those cases in which the syllable structure of the nonce words triggers stress either on the antepenult or on the final. In these cases, this variability seems to be due to the fact that the speakers have the possibility to either create a disyllabic trochee on the left margin or a bimoraic trochee on the right margin, as for example in the LLH condition, where the optimal parsing can both be (Ĺ L)(H̀) or (L̀ L)(H́).

7.4.4 Discussion of results of the nonce words with secondary stress

In this section, the results concerning the nonce words aimed at investigating secondary stressed are discussed. For ease of reference, table (29) containing the results concerning secondary stress is reported again here.

Table (29). Results for the nonce words aimed at investigating secondary stress

	Type of heavy syllable	**Structure**	**Example**	**Stress on 1° σ**	**Stress on 2° σ**	**Total**
34.	[None]	LLLY(X)[89]	Ma.la.ko.rísmus	80.34% (94)	19.6% (23)	117 (-3)
35.	Coda	LHLY(X)	Ro.den.ko.líeren	44.95% (49)	55.04% (60)	109 (-11)
36.	Falling diphthong	LHLY(X)	Ta.rau.po.lísmus	18.51% (20)	81.48% (88)	108 (-12)
37.	Double onset	LHLY(X)	Se.tro.la.níeren	81.90% (86)	18.09% (19)	105 (-15)

Looking at table (29), with respect to the condition with no heavy syllables, LLLY(X), (34.), it is possible to see that secondary stress falls most of the times on the first syllable (80.34%), confirming that the default position of secondary stress is on the first syllable and that the directionality of secondary stress is from left to right, meaning that a trochaic foot is built on the left margin of the word, as in *(Mà.la).ko.rísmus*, instead of **Ma.(là.ko).rísmus.*

[89] L = light syllable, H = heavy syllable, Y = syllable bearing primary stress, (X) = optional unstressed syllable of any type present only in some of the nonce words as part of the primary stress-bearing suffix.

With respect to the condition with a second syllable with a consonant in the coda, LHLY(X)-CVC) (35.), the results show that, in comparison with the LLLY(X) condition, stress is shifted mostly to the second heavy syllable, from 19.6% of secondary stress on the second syllable in LLLY(X) to 55.04% of secondary stress on the second syllable in the condition with a second syllable with a consonant in the coda. Since the difference between the two conditions is statistically highly significant, this suggests that the second heavy syllable attracts stress, although the first syllable still receives stress almost half of the times (44.95%).

With respect to the condition with a second syllable with a falling diphthong, LHLY(X)-CVG), (36.), the results show that, in comparison to the LLLY(X) condition, stress is shifted considerably to the second heavy syllable, from 19.6% of secondary stress on the penult in LLLY(X) to 81.48% of secondary stress on the penult in the condition with a second syllable with a falling diphthong. Since the difference between the two conditions is statistically highly significant, this suggests a clear influence of the second heavy syllable in attracting secondary stress.

Furthermore, since the difference between the condition with a second syllable with a consonant in the coda (CVC, 35.) and the condition with a second syllable with a falling diphthong (CVG, 36.) is statistically highly significant ($p < .001$), this suggests that a syllable with a falling diphthong attracts secondary stress significantly more often than a syllable with a consonant in the coda, meaning that a syllable with a falling diphthong counts as a superheavy syllable, as was found to be the case also for primary stress.

With respect to the condition with a second syllable with a double onset, LHLY(X)-CCV, (37.), the results show that secondary stress falls mostly on the first syllable, in an equal amount to the LLLY(X) condition (81.90% in the former vs 80.34% in the latter) and the difference between the two conditions is not statistically significant, suggesting that a second syllable with a double onset does not attract secondary stress.

Concerning possible effects due to individual variation, the results of a mixed-effects logistic regression analysis indicate no effect of sex ($p = 0.8174$) or age ($p = 0.2330$). However, there seems to be an effect of state (*Land*). Using the state of Hessen, which was the most represented, as reference state, the results indicate that both participants from Bavaria (odd ratio = 0.174, $p = 0.01$) and participants from Saxony (odd ratio = 0.087, $p = 0.04$) have a lower probability of collocating stress on the first syllable than participants from Hessen.

Overall, the results confirm that secondary stress in German has a directionality from left to right, i.e. a default position on the first syllable, and that a second syllable with a consonant in the coda (CVC) counts as heavy, while a second syllable with a falling diphthong (CVG) counts as superheavy. On the contrary, a second syllable with a double onset (CCV) does not count as heavy.

These results match precisely those found in the case of primary stress (limited to the types of heavy syllables that have been investigated for secondary stress), suggesting the secondary stress in German is weight-sensitive in the same way as primary stress, in accordance with typological data. Furthermore, the results indicate that some of variability in the collocation of secondary stress might be related to diatopic variation.

7.5 Conclusions

Overall, the results with respect to primary stress in 3-syllable nonce words confirm that the syllable which plays the major role with respect to stress assignment in German is the final syllable, as was also found in previous studies. More specifically, both a syllable with a consonant in the coda (CVC) and a syllable with a long vowel (CVV) in final position have been found to attract stress significantly more often with respect to the LLL condition. Furthermore, both a syllable with two consonants in the coda (CVCC) and a syllable with a falling diphthong (CVG) have been found to attract stress significantly more often with respect to a syllable with a consonant in the coda (CVC) and to a syllable with a long vowel (CVV), suggesting that CVCC and CVG should be considered as superheavy syllables. These results suggest a three-way contrast of syllable weight in German with respect to the final syllable, according to the hierarchy CVCC, CVG > CVC, CVV > CV. A syllable with a double onset (CCV) in final position seems also to attract stress, although only to a limited extent, confirming the weak influence of onsets with respect to stress assignment also found in previous studies.

With respect to the penultimate syllable, the LHL condition does not allow to clearly see the influence of heavy penult with respect to the LLL condition, since the percentages of stress between the two conditions are very similar, suggesting that, if the final syllable is light, stress falls on the penult by default. Nonetheless, an effect of a syllable with a consonant of the coda (CVC) in penultimate position seems to emerge, since in this type of syllable stress is placed significantly more often on the penult than in LLL. On the contrary, the influence of a heavy penult seems to be more clearly visible in the LHH word type. In particular, when comparing LHH with LLH, the penultimate syllable with a long vowel (CVV) in LHH attracts stress significantly more often than a penultimate syllable in LLH and a penultimate syllable with a diphthong (CVG) in LHH attracts stress significantly more often than a penultimate syllable with a long vowel in LHH. These data suggest that the influence of a penultimate heavy syllable becomes more evident only if the final syllable is also heavy. More specifically, these results confirm that also in penultimate position a syllable with a long vowel counts as heavy and a syllable with a diphthong counts as superheavy.

Somewhat unexpectedly, a syllable with a consonant in the coda (CVC) in penultimate position in LHH was not found to attract stress significantly more than the penultimate syllable in LLH, perhaps due to a size effect.

With respect to the antepenultimate syllable, the results of the HLL condition suggest that the structure of the antepenult does not play a role in stress assignment in German in these types of words, confirming the results found in previous studies according to which, if the final syllable is light, stress falls by default on the penultimate syllable.

With respect to the comparison of 2-syllable nonce words with 3-syllable nonce words, the results suggest that in all types of 2-syllable nonce words (LL, HL, LH, where H is always CVC) stress tends to be placed mostly on the penult, allowing full parsing of each word type into a disyllabic trochee, unlike in 3-syllable nonce words, in which more variation with respect to stress assignment is found, since full parsing is not possible. Nonetheless, the LH condition also shows a significantly higher percentage of stress on the heavy final (31.76%) with respect to LL and HL (0%), suggesting that the heavy final also in 2-syllable nonce words exerts an influence, although this influence seems to be mostly overridden by the tendency to achieve full parsing.

With respect to 4-syllable nonce words, in which only CVC, CVCC and CVG were tested as potential heavy syllables, the results mirror precisely those found in the 3-syllable nonce words, in that, in final position, both a syllable with two consonants in the coda (CVCC) and a syllable with a diphthong (CVG) attract stress more often than a syllable with a consonant in the coda (CVC), which in turn attracts stress more often than a light syllable (CV). The results of 4-syllable nonce words also confirm the influence of a CVC syllable in penultimate position (as found in LHL) and also of a CVG syllable in penultimate position (which was not found however in LHL but rather in LHH). The results of 4-syllable nonce words also confirm no influence of a heavy syllable in antepenultimate position.

With respect to the possible effect of full parsing in 4-syllable nonce words, the results of the comparison with the respective 3-syllable nonce words indicate that an effect of full parsing is present in 4-syllable nonce words, but only in those with a final heavy syllable (LLLH). Namely, in all types of LLLH nonce words (either with a final CVC, CVCC or CVG), stress is placed significantly more often on the penultimate syllable with respect to the respective 3-syllable nonce words, allowing to achieve full parsing into two trochaic feet in the former. In the case of LHLL and LLHL, there is always a numerical increase of stress on the penult with respect to their respective 3-syllable nonce words, however the increase is never significant, probably due to the fact that stress is already predominantly on the penult in their respective 3-syllable nonce words, suggesting that the tendency to achieve full parsing perhaps is also present in LHLL and LLHL but it is not clearly visible.

With respect to secondary stress, the results of the LLLY(X) condition confirm that secondary stress in German has a directionality from left to right, i.e. the default position of secondary stress is on the first syllable, as found in previous studies.

The results of the LHLY(X) condition indicate that a heavy syllable with a consonant in the coda (CVC) in second position attracts secondary stress significantly more often with respect to the condition with no heavy syllables and that a heavy syllable with a falling diphthong (CVG) in second position attracts secondary stress significantly more often than a heavy syllable with a consonant in the coda (CVC), confirming, as was found in the case of primary stress, a three-way contrast of syllable weight for secondary stress in German, according to the hierarchy CVG > CVC > CV (the CVCC and CVV syllables were not investigated in the case of secondary stress). However, no effect of a syllable with a double onset (CCV) in second position was found.

Overall, secondary stress seems to show the same sensitivity to syllable weight that was found in the case of primary stress.

8 Corpus analysis: research questions

The aim of this thesis is to understand the relationship between syllable structure and stress position in Italian and German. This is done first through a nonce word experiment, and then through a corpus analysis in the lexicon of the two languages. These two methodologies are thus both aimed at investigating the same phenomenon, i.e. the algorithm underlying the placement of stress and the role that syllable weight plays in it, from two different points of view.

More specifically, the nonce word experiment investigates such algorithm as part of the speakers' linguistic *competence,* assuming that the algorithm is encoded in the speakers' mind. The corpus analysis investigates the same algorithm, looking instead at how it is manifested in the real lexicon. The only difference between the two analyses concerns that fact that, while in the nonce word experiments both primary and secondary stress will be investigated, in the corpus analyses only primary stress will be investigated, since, with respect to both the Italian and German lexicon, there is no consensus on the exact position of secondary stress for every type of words (see sub-chapters 3.4 and 4.4).

The corpus analysis is thus aimed at answering the same research questions of the nonce word experiment. For this reason, the research questions concerning primary stress already reported in chapter (5) will be reported again here in (52):

(52) Research questions of the corpus analysis related to primary stress:

1. Is primary stress sensitive to syllable weight and to which extent?
2. What types of syllables count as heavy, i.e. attract stress, and how do different types of heavy syllables differ in their role in stress assignment?
3. What syllable positions within the word are relevant for stress assignment and how do different syllable positions differ in their role in stress assignment?
4. Does syllable weight interact with parsing of a word into feet?

However, in spite of the fact that both the nonce word experiment and the corpus analysis should reflect the same algorithm for stress assignment, it is still possible that the two analyses will yield slightly different results, because the patterns that characterize the speaker's competence might not necessarily reflect the patterns found in the lexicon in a straightforward way.

More specifically, with respect to the relationship between the speaker's competence, reflected in the nonce word experiment, and the lexicon, reflected in the corpus, the question arises of whether the former is strictly derived from the latter or not.[90]

A first broad hypothesis might be that the algorithm underlying the speaker's competence for stress assignment is built from the input represented by the lexicon to which speakers are exposed during language acquisition. Under this view, it is to be expected that the stress patterns that result from a nonce word experiment and those that result from a corpus analysis should to some extent coincide. In this respect, the corpus analysis should thus be seen as a way to further corroborate the results of the nonce word experiment. Under this hypothesis, some level of mismatch between the results of the nonce word experiment and of the corpus analysis might still be present due to the way in which speakers generalize the patterns found in the lexicon to the nonce words. To cite just one example, assuming that the hypothesis under discussion is true, it is an open question whether, when stressing the nonce words, which are morphologically simple, speakers also access morphologically complex words, such words including derivational prefixes or suffixes, or compounds.

The hypothesis opposite to the one just discussed would be that the algorithm for stress assignment is not directly derived from the lexicon, rather the patterns found in the lexicon are supposed to be shaped through the historical development of the language by the abstract rules of stress assignment that are part of the speaker's competence. Under this view, some level of mismatch between the results of the nonce word experiment and of the corpus analysis might be due to the fact that the lexicon contains some fossilized forms that do not reflect the productive rules that are currently active in the speaker's mind.

Although the current work is not aimed at analyzing the precise relationship between the speaker's competence and the lexicon with respect to stress assignment, the above mentioned hypotheses and their implications should still be taken into account when analyzing the results of the two analyses.

[90] For a discussion see also Domahs *et al.* (2014) and their distinction between analogical *vs* rule-based models.

9 Corpus analysis of stress: Italian

9.1 Research questions

The main aim of the corpus analysis on stress is to further corroborate the results of the nonce word experiment. The research questions that the corpus analysis is aimed at investigating are thus the same that are investigated in the nonce word experiment. The general research questions concerning the nonce word experiment were presented in chapter 5, while the specific research questions concerning stress and syllable weight in Italian were presented in sub-chapter 6.1.

However, besides the aim of corroborating the results of nonce word experiment, when comparing the results of a corpus analysis with those of a nonce word experiment the question also arises to which degree the results of the two analyses should be expected to match and also whether and to which extent the stress patterns applied to the nonce word can be assumed to derive from the lexicon. This issue and the relevant hypotheses are discussed in the chapter on the general research questions concerning the corpus analysis of stress (chapter 5).

Although the detailed discussion on the research questions can be found on the above mentioned chapters, the main points could be summarized as following.

With respect to the influence of syllable weight on primary stress in Italian, in the case of 3-syllable (nonce) words, the expectations are that a penultimate heavy syllable attracts stress. On the contrary, a heavy antepenult is not expected to attract stress. In the case of 4-syllable nonce words, the expectations are that the percentage of stress on the penult increases with respect to the 3-syllable words in order to allow full parsing of the 4-syllable words into trochaic feet (L̀L)(ĹL).

With respect to secondary stress, in this corpus analysis the relationship between syllable weight and secondary stress could not be investigated, since, as discussed in chapter 3, there is no universal agreement on secondary stress position or even on its existence in Italian, so no corpus can be found containing reliable and unambiguous information on secondary stress position.

9.2 Methodology

In order to investigate the relationship between syllable weight and primary stress in Italian, a specific type of corpus was necessary, containing a list of Italian lemmas with the following characteristics: phonetic transcription, including stress position, and division into syllables. Such a corpus was retrieved by a GitHub repository (https://github.com/Kyubyong/pron_dictionaries#work-flow, accessed on January 2021) containing pronunciation dictionaries for different languages, which have been extracted from Wiktionary. The Italian dictionary contains about 30.000 lemmas written in SAMPA, a computer-readable set of characters used to represent the IPA symbols. This corpus contains phonetic transcription, including stress, but not division into syllables. In order to make the corpus more readable and to adapt it to the needs of the corpus analysis on stress, the SAMPA symbols have been converted into IPA symbols using a Python script. Then, a set of regular expressions have been written, which allow to divide words written in IPA into syllables, according to the Italian syllable structure. Such regular expressions have been applied to the corpus using Python, also numerating each syllable in each lemma. The final result is thus a corpus of about 30.000 Italian lemmas written in IPA with stress marked and each lemma divided into syllables. An example for the lemma *conchíglia* 'shell' is *3kon2'kiʎ1ʎa.*

All lemmas in the corpus have subsequently been manually checked for errors, such as mistakes in transcriptions, inflected words or duplicates, and all the detected errors have been corrected. Furthermore, all words that were deemed too technical or obsolete were deleted from the corpus, as well as occasional proper names. The final complete corpus contained 28.577 lemmas. In spite of the general check-up, it is still possible of course that some mistakes might have remained. The lemmas contained in the corpus include both morphologically simple words, such as *banána* 'banana' and morphologically complex words, including compounds, such as *in+evitá+bile* 'unavoidable' or *porta#ombrélli* 'umbrella stand'.

In order to count the number of words with a specific syllable structure and number of syllables and a specific stress position, a new set of regular expressions which allowed to extract the relevant patterns from the corpus have been written and implemented in Python (see appendix 15).

Since the main aim was to compare the results of the corpus analysis with those of the nonce word experiment, the analysis was only run on 3- and 4-syllable words, which are the word structures investigated in the nonce word experiment. Words with final stress (which represent only 2% of the total, see below) were also excluded from the analysis, since final stress was not a possible accentuation in the nonce word experiment.

The corpus analysis was carried out matching the exact structures of the nonce words, which meant including the presence of always at least one segment in the onset, as was the case for all nonce words. This meant that, for example, when comparing the results of the nonce word experiment and of the corpus analysis for the CV.CV.CV condition, words such as *vi.a.le* CV.V.CV were not included, since one or more of the syllables is lacking the onset.[91]

[91] However, it remains an open question whether speakers take into account the presence of the onset when generalizing the stress patterns from the lexicon to the nonce words. For example, it is unclear whether a word such as *i.dé.a* 'idea',

9.3 Results

The following tables show the results with respect to the distribution of stress in 3- and 4-syllable words. In some cases, the sum of the accentuations on each syllable of a word type (and as a consequence the percentages) do not add up exactly to the total because of the presence of occasional errors in the corpus which have remained in the final analysis (this is the case for example of words with no stress marked by mistake). For ease of comparison, the results of the corpus analysis are paired with those of the nonce word experiment.

A chi-square test has been performed for each condition, comparing the results of the experiment with those of the corpus analysis. If the difference between the two sets of results is statistically highly significant ($p < 0.001$) the row for that condition is highlighted in dark blue, while if the difference is statistically marginally significant ($p < 0.05$) the row for that condition is highlighted in light blue. The LLL condition is also always highlighted in grey. As mentioned above, since the results are expected to be similar, for each condition, the difference between the two analyses is expected not to be statistically significant.

Overall, out of 28,576 words, 7238 were 3-syllable words. The general distribution of stress in 3-syllable words is reported in figure (5). The comparison of the results of the experiment and the corpus analysis for the 3-syllable words is given in table (30), while the comparison of the results for the 4-syllable words is given in table (31).

In each table, the 'Example' column of each condition, the first word is an example of a nonce word, the second word is an example of a real word with stress on the syllable which was stressed more often in the corpus in that condition.

where the antepenult and final are onsetless (V.CV.V), would be recalled when a speaker is asked to stress a nonce word of the CV.CV.CV type.

Figure (5). Distribution of stress in 3-syllable words in Italian.

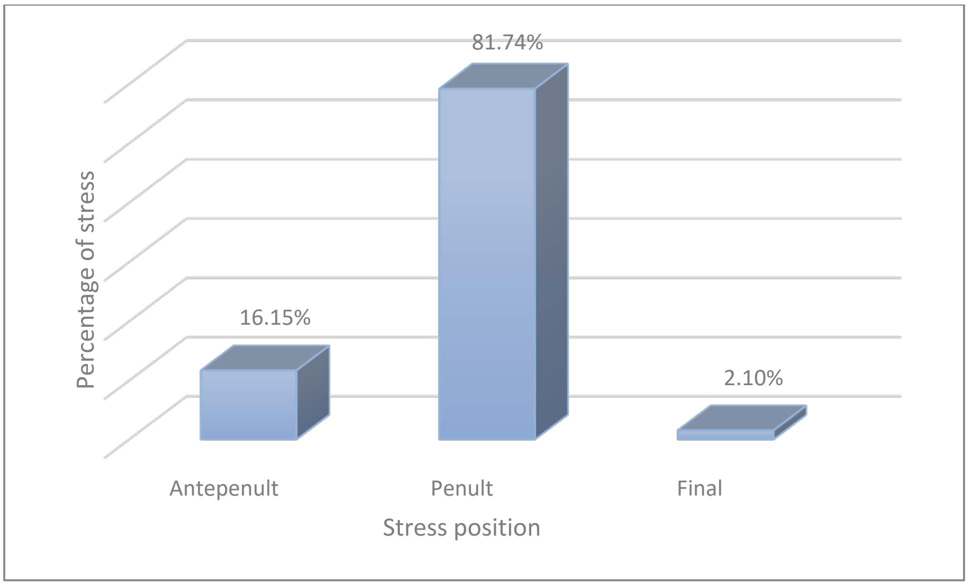

Table (30). Comparison of the results of the experiment and the corpus analysis for the 3-syllable words.

				Experiment		**Corpus**	
Condition	**Type of heavy syllable**	**Structure**	**Example**	**Stress on A**	**Stress on P**	**Stress on A**	**Stress on P**
1.	[None]	LLL	fa.na.bo ba.ná.na	17.41% (31)	82.58% (147)	30.02% (303)	65.70% (663)
2.	Coda	HLL	zen.to.fa bal.lá.re	12.50% (22)	87.50% (154)	27.67% (318)	69.79% (802)
3.		LHL	ne.loc.co co.pér.ta	0% (0)	100% (177)	0.36% (2)	96.73% (534)
4.	Rising diphthong	HLL	pia.va.fo fiu.tá.re	15.66% (13)	84.33% (70)	21.91% (16)	73.97% (54)
5.		LHL	co.ria.ba se.guí.re	1.13% (1)	98.86% (87)	3.26% (3)	93.47% (86)
6.	Falling diphthong	HLL	lau.si.fo neu.rá.le	7.86% (7)	92.13% (82)	30% (3)	60% (6)
7.		LHL	da.nei.pa giu.dái.co	0% (0%)	100% (76)	0% (0)	100%[92] (4)
8.	Vowel sonority	HLL	ra.si.fa fa.rí.na	14.44% (13)	85.55% (77)	34.74% (41)	53.38% (63)
9.		LHL	cu.va.fe pi.rá.ta	7.77% (7)	92.22% (83)	7.86% (7)	92.13% (82)
10.	Double onset	HLL	tra.fa.bo bra.vú.ra	16.94% (20)	83.05% (98)	25.88% (95)	70.29% (258)

[92] For this condition it was not possible to run the chi-square test, since in both cases the number of stress on the antepenult was equal to 0. However, since both in the results of the corpus and in those of the experiment stress is attracted categorically on the penult (100%) the two results can be considered not significantly different.

11.		LHL	na.tra.bo so.vrá.no	12.82% (15)	87.17% (102)	8.39% (11)	82.44% (108)
12.	Triple onset	HLL	sgre.ve.pa spre.cá.re	11.11% (13)	88.88% (104)	23.52% (8)	76.47% (26)
13.	Historical factor (onset)	HLL	psa.na.fo cla.mó.re	15.38% (18)	84.61 (99)	45.83% (11)	54.16% (13)
14.	Historical factor (diphthong)	LHL	ga.lie.po ri.lié.vo	0% (0)	100% (116)	0% (0)	100%[93] (43)

Table (31). Comparison of the results of the experiment and the corpus analysis for the 4-syllable words.

				Experiment		**Corpus**	
Condition	**Type of heavy syllable**	**Structure**	**Example**	**Stress on A**	**Stress on P**	**Stress on A**	**Stress on P**
15.	[None]	LLLL	me.ro.ne.fa ca.la.mí.ta	14.18% (20)	85.81%[94] (121)	27.65% (250)	66.03% (597)
16.	Coda	LHLL	ga.ral.ca.fo pa.ral.lé.lo	13.47% (19)	86.52% (122)	25.10% (123)	72.85% (357)
17.		LLHL	fa.ra.lan.go de.ca.deń.te	0% (0)	100% (149)	0.28% (1)[95]	99.15% (353)
18.	Rising diphthong	LHLL	ru.lia.ne.po cu.rio.sá.re	3.52% (3)	96.47% (82)	28.57% (16)	58.92% (33)
19.		LLHL	go.na.ria.fo di.vi.sió.ne	0% (0)	100% (83)	0% (0)	98.71%[96] (77)
20.	Falling diphthong	LHLL	la.rai.bo.fa [none]	8.23% (7)	91.76% (78)	0% (0)	0% (0)
21.		LLHL	za.no.rai.po pa.ra.nói.co	0% (0)	100% (87)	0% (0)	100%[97] (4)

[93] For this condition it was not possible to run the chi-square test, since in both cases the number of stress on the antepenult was equal to 0. However, since both in the results of the corpus and in those of the experiment stress is attracted categorically on the penult (100%) the two results can be considered not significantly different.

[94] This condition contained one nonce word (*bituripo*) which, unlike the others, was stressed most frequently on the antepenult, probably because of its resemblance with some real words with stress on the antepenult. If this item is removed from the analysis, the percentages change considerably, yielding 97.29% of stress on the penult (see discussion in sub-chapter 6.3).

[95] In this corpus, the only 4-syllable word with a consonant in the coda in the penult and stress on the antepenult is *canéderlo* (a kind of bread dumpling from South Tyrol), which is an adapted loanword from German *Knödel.*

[96] For this condition it was not possible to run the chi-square test, since in both cases the number of stress on the antepenult was equal to 0. However, since both in the results of the corpus and in those of the experiment stress is attracted categorically on the penult (100%) the two results can be considered not significantly different.

[97] For this condition it was not possible to run the chi-square test, since in both cases the number of stress on the antepenult was equal to 0. However, since both in the results of the corpus and in those of the experiment stress is attracted categorically on the penult (100%) the two results can be considered not significantly different.

9.4 Discussion of results

The general distribution of stress in 3-syllable words reported in figure (5), confirms the results of other corpus analyses (Borelli 2002, cited in Krämer 2009), in that, overall, pooling together all types of 3-syllable words, stress falls most frequently on the penult (81.74%), which can be considered the default position, followed by the antepenult (16.15%) and by the final (2.10%).

With respect to the comparison between the results of the nonce word experiment and the corpus analysis for the 3- and 4-syllable nonce words, overall, it can be seen from table (30) and (31) that, for each condition, when stress is placed most frequently on the penult in the experiment this is also the case in the corpus analysis, although the frequency with which stress is assigned to the penult in the experiment and the corpus differ in the various conditions. These results confirm that overall there is a clear relationship between the real lexicon and the mental algorithm for stress assignment manifested in the nonce words.

More specifically, with respect to those conditions in which stress is attracted categorically (almost 100%) by a specific syllable in the nonce words, it can be seen that the same happens also in the corpus. Namely, for both the 3- and 4-syllable words, a penult with a coda (3., 17.), a penult with a rising diphthong (5., 19.), a penult with a falling diphthong (7., 21.) or a penult with a historical diphthong (14., analyzed only in 3-syllable words) attracts stress almost 100% of the time both in the experiment and in the corpus. The same happens also for the vowel sonority condition, (9., analyzed only in 3-syllable words), in which a low vowel on the penult attracts stress almost categorically (about 90%) in both the experiment and the corpus. As further support for the strong relationship between the two analyses it should also be noted that in these conditions the difference between the experiment and corpus is systematically not statistically significant. These results of the corpus analysis thus confirm the influence of syllable weight for the above mentioned syllable structures in penultimate position.

However, in the cases in which there is not a clear influence of syllable weight (for example when the heavy syllable is in antepenultimate position), the degree of similarity between the experiment and the corpus varies quite considerably, although, as mentioned, in each condition the most frequently stressed syllable in the experiment is always also the most frequently stressed syllable in the corpus. To cite just one example, in the condition with syllable with a consonant of the coda in antepenultimate position (2.) stress falls mostly on the penult in both analyses, but in the nonce word experiment stress falls on the penult 87.50% of the times, while in the corpus only 69.79% of the times.

In some of these conditions that show variation between the corpus and the experiment, the degree of variation is actually low and, on the basis of a chi-square test, it is not statistically significant, so that in these cases the two sets of results could be considered comparable. This occurs in the condition with a rising diphthong in the antepenult (4.), a double onset in the penult (11.) and a triple onset in the antepenult (12.), all in the 3-syllable words.

However this is not the case for all the other remaining conditions, in which the disparity between the experiment and the corpus remains unexplained.

In some cases, the disparity between the corpus and the experiment could be attributed to the low number of words with a particular structure present in the real lexicon. This could be the case of the 3-syllable words with a falling diphthong in the antepenult (6.) and the historical onset in the antepenult (13.), which in the lexicon were represented only by 9 and 24 words respectively, making the respective percentage values concerning stress position unreliable.

In the case of the historical onset, the disparity between the experiment and the corpus (84.61% and 54.16% of stress on the penult respectively) could also be interpreted in two different ways: under the assumption that the results of the nonce words are derived from those of the corpus, the partial mismatch between the two analyses could be interpreted as an indication that speakers, when stressing the nonce words, are not sensitive to the specific segments that form the complex onset (e.g. (/kl/, /st/ etc.), but rather only to the abstract structure of 'complex onset' (CCV). This would imply that, when stressing a nonce word with an onset /kl/, the speakers do not access only to all real words with an onset /kl/ but rather to all real words with a double onset (CCV), irrespective of the specific phonemes that characterize the onset, with the result that they would stress a nonce word with an onset /kl/ in the same way in which they would stress any nonce word with a double onset. Under the opposite assumption, i.e. that the results of the corpus are due to the implementation of the mental algorithm, manifested in the results of the nonce words, to the real lexicon through the historical development of the language, one interpretation for the mismatch could be that, in words with a historical cluster, the higher percentage of stress on the antepenult found in the corpus with respect to the experiment might be due to the fact that this type of words in the corpus is characterized mostly by fossilized forms that did not underwent the application of the phonological rules for stress assignment that characterize other layers of the lexicons, with the consequence that the words with a historical cluster have a higher percentage of stress on the antepenult than expected.[98]

[98] As mentioned in chapter (x), the *latinismi* should indeed be associated with a higher percentage of stress on the antepenult with respect to other types of words.

In all the remaining conditions, the difference between the experiment and the corpus is statistically significant ($p < 0.001$ or, in two cases, $p < 0.05$) and cannot be explained by the small number of words present in the corpus. These conditions are, in 3-syllable words: the condition with no heavy syllables (1.), a coda in the antepenult (2.), a low vowel in the antepenult (8.) and a double onset in the antepenult (10.). In the 4-syllable words, they are: the condition with no heavy syllables (15.), a coda in the antepenult (16.) and a rising diphthong in the antepenult (18.).

For example, looking at the LLL condition (1.) in 3-syllable words, it can be seen that, in the corpus, stress is found on the penult 65.70% of the times (still confirming the default position of stress on the penult), however, this percentage differs greatly from the one found in the experiment, which is 82.58% of stress on the penult.

Under the assumption that participants derive the stress patterns applied to the nonce words from the real lexicon, it might be possible that speakers are sensitive to specific factors found only in the real lexicon which are responsible for the difference between the results of the experiment and of those of the corpus. One of this factors could be for example morphology, which as mentioned above could not be controlled for in the corpus. For example, the corpus might contain many words with suffixes associated with antepenultimate stress, such -*bile*, e.g. *amábile* 'lovable', or -*ico*, e.g. *cómico* 'comical' and speakers might instead generalize the stress patterns to the nonce words only from morphologically simple words in the real lexicon. Another factor could that might explain the mismatches between the experiment and the corpus, could be that speakers are sensitive only to a specific segmental structure, as already hypothesized to explain the results concerning the historical onset (see above). As an exploratory analysis aimed at understanding more in detail the role of specific segmental structures, I recalculated the percentages of stress for LLL derived from the corpus by varying the specific segmental structure of the onset. The hypothesis that is tested is whether the accentuation of a CV.CV.CV nonce word might be influenced also by real words with open syllables with no onset, i.e. with a (C)V.(C)V.(C)V structure. As an example, a question that can be investigated is whether a nonce word like *fa.na.bo* CV.CV.CV is influenced in its accentuation also by a real word like *vi.a.le* 'boulevard' CV.V.CV. The results of this new corpus analysis for the LLL condition including also (C)V.(C)V.(C)V words however made the percentage slightly farther away from those found in the nonce words experiment (which was 82.58% of stress on the penult). More specifically, this new corpus analysis yielded 63.67% of stress on the penult *vs* the standard corpus analysis reported in table (30), with exactly one segment in the onset for each syllable CV.CV.CV, which yielded 65.70% of stress on the penult. I also ran an analysis including all types of onset, including no onset, i.e. with a (CCC)V.(CC)V.(CC)V structure. This was done in order to analyze whether the onset structure plays a role at all. This analysis however did not make the percentages much closer to those of the nonce word experiment, yielding only 67.07% of stress on the penult vs. 65.70% of stress on the penult of the standard analysis. These alternative analyses suggest that, assuming that speakers generalize the patterns in the nonce words from the real lexicon, they do so by looking at real words with the exact same segmental structure of the nonce words, at least with respect to onset structure.

A different explanation to account for the difference between the results of the corpus and the experiment might be that, assuming that speakers generalize the patterns in the nonce words from the real lexicon in the corpus, in the case of conditions in which syllable weight works in an (almost) categorical way (a penult with a coda (3., 17.), rising diphthong (5., 19.), falling diphthong (7., 21.), historical diphthong (14.,) and low vowel (9.)), speakers apply the same patterns present in the real lexicon to the respective nonce words. On the contrary, in the case of the conditions in which syllable weight does not play a (clear) role (i.e. all the other remaining conditions), it might be possible that speakers, when stressing the nonce words, disregard the exact distribution present in the real lexicon, and simply assign stress following the default position. Since from the LLL condition in the nonce word experiment it turned out that the default position of stress is about 80% on the penult, the consequence would be that speakers stress all non-weight-sensitive conditions like they would stress the LLL condition, i.e. about 80% of stress on the penult. This is indeed what has been mostly found in the nonce word experiment. This explanation, however, still does not account for the mismatch in the LLL condition, in which, in the experiment stress is placed on the penult 82.58% of the times, while in the corpus only 65.70% of the times.

A different explanation to account for the fact that the results of the experiment and of the corpus analysis always match with respect to the conditions in which there is a categorical influence of syllable weight and less frequently with respect to the other conditions might be formulated assuming the opposite hypothesis as above, i.e. that the patterns in the corpus are the results of the implementation of the mental algorithm represented in the nonce words throughout the history of the language. More specifically, under this hypothesis, the results concerning the matching conditions (i.e. those with a heavy penult) could be interpreted as due to the fact that the rules concerning the influence of syllable weight are applied without exceptions in the lexicon throughout the development of the language. On the contrary, the results concerning the non-matching conditions (i.e. those with a heavy antepenult) could be due to the fact that perhaps the heaviness of the antepenultimate syllable has changed throughout the history of the language, so that some of the words in the real lexicon show an unexpectedly high percentage of stress on the antepenult because they are fossilized forms that reflect an older stage of the history of the language, in which the antepenult might have played a role in attracting stress.

With respect to 4-syllable words, it was expected that speakers would tend to place stress on the penult more frequently than in 3-syllable words, since the structure of the 4-syllable words would allow to achieve full parsing of the word into two trochaic feet (L̀L)(ĹL), which is not possible in the case of 3-syllable words, since this would cause a stress clash *(L̀)(ĹL).

However, the results of the corpus analysis indicate that stress in 4-syllable words is placed on the penult as much as in 3-syllable words, i.e. 66.03% and 65.70% of the times respectively. On the contrary, in 4-syllable words in the nonce word experiment stress fell on the penult 97.29% of the times (if one excludes the one item which exceptionally triggered stress mostly on the antepenult, see note 92 in table 31) and 82.58% in the 3-syllable words, suggesting that there is a tendency to achieve full parsing in 4-syllable words.

If one assumes that, in the case of 3-syllable words, the difference in stress patterns between the experiment and corpus (82.58% and 65.70% of stress on the penult respectively) is not really significant but rather due to some of the factors discussed above and that in the 4-syllable words the difference between the experiment and corpus is instead significant (97.29% and 66.03% of stress on the penult), one interpretation could be that, assuming speakers derived the pattern in the nonce words from the lexicon, in the 3-syllable words, when speakers stress nonce words they tend to emulate exactly the stress patterns of the real lexicon, since there is no possibility to achieve full parsing. On the contrary, in the 4-syllable words, since, unlike the 3-syllable words, there is the context for full parsing, speakers do not consider the patterns in the real lexicon (which do not have more stress on the penult than the 3-syllable words), but rather stress the nonce words implementing the full parsing, since they have the possibility to do so.

On the contrary, under the opposite hypothesis that patterns in the nonce words have been applied to the lexicon throughout the historical development of the language, the same considerations made above for 3-syllable words might be applied also to 4-syllable nonce words, i.e. with respect to the matching conditions (i.e. those with a heavy penult) the rules concerning the influence of syllable weight are applied without exceptions in the lexicon throughout the development of the language. On the contrary, with respect to the non-matching conditions (i.e. those with a heavy antepenult) the heaviness of the antepenultimate syllable might have changed throughout the history of the language, so that some of the words in the real lexicon show an unexpectedly high percentage of stress on the antepenult because they are fossilized form that reflect an older stage of the history of the language, in which the antepenult might have played a role in attracting stress.

In summary, the results of the corpus analysis confirm the results of the nonce word experiment in that a penult with a coda and a penult with a diphthong (rising, falling or historical) attract stress categorically. Also a penult with the low vowel /a/ in both analyses attracts stress almost categorically (about 90%). With respect to all other conditions, the results of the corpus analysis match with those of the experiment in that the most stressed syllable in the corpus is also always the most stressed one in the experiment, although to different degrees in the various conditions.

With respect to 4-syllable words, the results of the corpus analysis suggest that 4-syllable words do not show a higher percentage of stress on the penult than 3-syllable words, i.e. a tendency to achieve full parsing of the word, unlike what was found in the experiment. This might suggest that the tendency to achieve full parsing might not derive from the lexicon, but it is rather implemented by the speakers when they have the possibility to do so, i.e. when stressing the nonce words, irrespective of the stress patterns in the lexicon.

With respect to the issue of the relationship between the patterns in the nonce words and the real lexicon two main hypotheses have been introduced in the discussion above: under one hypothesis (1), the speakers generalize the patterns in the real lexicon to the nonce words. Under the opposite hypothesis (2), the patterns in the real lexicon reflect the application of some phonological rule concerning stress assignment throughout the historical development of the language.

Both hypotheses can explain some of the results found in the comparison between the nonce word experiment and the corpus analysis, especially with respect to the cases in which there is a mismatch between the two analyses, i.e. the conditions with a heavy syllable in antepenultimate position and conditions with only light syllables, in both of which there is a higher percentage of stress on the antepenult in the corpus with respect to the experiment.

More specifically, under hypothesis (1), the mismatch could be explained as due to the fact that the corpus also contains morphologically complex words, and the speakers might have instead generalized the patterns to the nonce words only form morphologically simple words. Under hypothesis (2), the mismatch could explained as due to the fact that the real lexicon in the corpus contained many fossilized forms that reflect older stages in the development of the language and older phonological rules that are no more active and that are thus not applied to the nonce words.

Overall, on the basis of these results alone, it is not possible to draw definitive conclusions concerning which of the two hypotheses might be the best one to account for all of the current data.

10 Corpus analysis of stress in German

10.1 Research questions

The main aim of the corpus analysis of stress is to further corroborate the results of the nonce word experiment. The research questions that the corpus analysis is aimed at investigating are thus the same that are investigated in the nonce word experiment. The general research questions concerning the nonce word experiment are presented in chapter 5, while the specific research questions concerning stress and syllable weight in German are presented in sub-chapter 7.1.

However, besides the aim of corroborating the results of the nonce word experiment, when comparing the results of a corpus analysis with those of a nonce word experiment the question also arises to which degree the results of the two analyses should be expected to match and also whether and to what extent the stress patterns applied to the nonce words can be assumed to derive from the lexicon or, conversely, to what extent the patterns in the lexicon are the results of the implementation of the stress algorithm to the real lexicon throughout the history of the language. This issue and the relevant hypotheses are discussed in the chapter on the general research questions concerning the corpus analysis of stress (chapter 5).

Although the detailed discussion of the research questions can be found in the above mentioned chapters, the main points will be summarized in the following paragraphs.

With respect to the influence of syllable weight on primary stress in German, considering the results of the nonce word experiment, in the case of 3-syllable words the expectations are that a final CVC syllable attracts stress. A penultimate CVC syllable might also attract stress, although not as strongly as a final heavy syllable. On the contrary, an antepenultimate CVC syllable is not expected to attract stress. A CVCC syllable in final position might count as a superheavy syllable, i.e. attracting stress more than a CVC syllable, while it is less clear if also a final CVG syllable should count as superheavy or simply heavy. A double or triple onset is expected to attract stress only slightly as a function of the number of segments in the onset.

In the case of 2-syllable words, the expectations based on the results of the nonce word experiment are that stress should fall mostly on the penult in all conditions. However, in the condition with a final CVC syllable the percentage of stress on the final is expected to increase in comparison to the condition with no heavy syllables.

In the case of 4-syllable nonce words, the expectations are that the percentage of stress on the penult increases with respect to the 3-syllable word in order to allow full parsing of the word into trochaic feet, but only in words with a final heavy or superheavy syllable.

With respect to secondary stress, in this corpus analysis the relationship between syllable weight and secondary stress could not be investigated, since, as discussed in chapter 4, there is no universal agreement on secondary stress position in German, so no corpus can be found containing reliable and unambiguous information on secondary stress position, for example for words with a possible secondary stress on the left margin, such as *Kàpazitǻt.*

10.2 Methodology

In order to investigate the relationship between syllable weight and primary stress in the German lexicon, it was necessary to find a specific type of corpus, containing a list of German lemmas with the following characteristics: phonetic transcription, stress position, and division into syllables.

The corpus with such characteristics that has been used in this analysis is the *CELEX2* corpus (Baayen *et al.* 1995). This corpus contains a list of lemmas with phonetic transcription, stress position and division into syllables for German, English and Dutch.

In order to run the analysis on German, the list of the German lexicon was manually cleaned by me from words which might be inflected or duplicates that might have been present. Furthermore, all words that were deemed too technical or obsolete were deleted. Compound forms were also deleted. The reason behind the choice of deleting compounds is that all the nonce words with which the real words are meant to be compared are monomorphemic. Furthermore, in German compounds stress usually falls on the first constituent of the compound, often on the first syllable of the word, so that keeping the compounds in the analysis would have resulted in an exceptionally high number of words with antepenultimate stress or even with pre-antepenultimate stress. On the contrary, none of the nonce words allow pre-antepenultimate stress, since in German monomorphemic words stress is restricted to the last three syllables. Morphologically complex words other than compounds, i.e. words with derivational suffixes, were instead kept in the corpus. This choice was due to the fact that, especially under the hypothesis that participants might generalize the patterns from the lexicon to the nonce words, it might be possible that they access also suffixed words, especially since the distinction between a morphologically simple and a morphologically complex word with respect to the presence of a suffix might not be always so clear-cut in the speaker's competence. For instance, the word *klugheit* 'intelligence' is likely to be clearly analyzed as made of *klug* 'smart' + the productive suffix *-heit,* while in the case of *tolerant* 'tolerant' and *imposant* 'impressive', both of which have the non-productive suffix *-ant,* the former might be perhaps analyzed as complex because of the presence of the verb *tolerieren* 'to tolerate' while the latter is likely to be analyzed as monomorphemic word, since it is not derivable by any word. As will be seen in the results section, morphology seems indeed to play a role and to interact with the stress assignment algorithm determined by syllable weight. For this reason, in specific conditions an alternative analysis reducing the influence of derivational suffixes has also been carried out by deleting words with suffixes that might be interpreted as productive.

After the manual modification, the final version of the corpus contained 3822 lemmas.[99]

One other aspect to note about the *CELEX2* corpus is that it also provides information on vowel length. However, as discussed in chapter (4), there is no unanimity on exactly which vowels in which positions count as long in German, and consequently also the decision to mark a certain vowel in a certain word as long in the *CELEX2* corpus is affected by a high degree of arbitrariness. Specifically, the *CELEX2* corpus tends to transcribe all tense vowels as long, so that the word *Melodíe* 'melody' is transcribed as [me:lo:ˈdi:], with all three vowels as long. While it is usually assumed that the final vowel in *Melodíe* is long, it is actually less clear that also the previous vowels should count as long. Because of the arbitrariness in marking vowel length, it has been decided to consider all vowels as short by default, except those in which vowel length is clearly indicated at the orthographic level, through the presence of grapheme clusters that unambiguously indicate that the vowel they represent is long, such as <ah>, <aa> (and their variants) and <ie>. This choice has of course the drawback that, when analyzing the distribution of stress in words that are not supposed to have long vowels (e.g. CV.CV.CV or CVC.CV.CV) some words that indeed have long vowels might be present, thus adding noise to the results. Another limitation is that, when analyzing the stress patterns in the conditions containing long vowels, such as CV.CVV.CV, it is to be expected that the corpus will not contain many non-compound forms of 3 and 4 syllables with the above mentioned grapheme clusters representing a long vowel, so that the results of the corpus analysis for the conditions containing long vowels will likely not be as informative as for the other conditions.

With respect to the extraction of the relevant data from the *CELEX2* corpus, a series of regular expressions have been written and implemented in Python, allowing to analyze the correlation between stress position and syllable structure for each lemma.

The corpus analysis was carried out by extracting lemmas that match exactly the structures of the nonce words for each category. For example, the CV.CVC.CV nonce words in the experiment were compared with the CV.CVC.CV real words in the corpus. As can be seen from the example just mentioned, all the extracted lemmas had always at least one segment in the onset, since all the nonce words had one. This means that, when comparing the results of the nonce word experiment

[99] The relatively low number of lemmas, especially if compared to the corpus analysis of Italian (see chapter 9), is due to the fact that in German, most 3- and 4- syllable words are compound words, such as *Brief+träger* 'postman', while in the present analysis only non-compound forms are considered, thus yielding a relatively low number of words.

and those of the corpus analysis, for example for the CV.CVG.CV condition a word such as *A.mei.se* 'ant' V.CVG.CV was not considered in the corpus analysis, since the first syllable is lacking the onset, unlike the corresponding nonce word.

The investigated structures for primary stress were the same as the ones investigated in the nonce word experiment, and thus included words with 2, 3 and 4 syllables with different types of heavy syllables in different positions (see tables (24), (25) and (27), in chapter (7)).

10.3 Results

The following tables show the results with respect to the distribution of stress in words with 2, 3 and 4 syllables extracted from the corpus. In some cases, the sum of the accentuations on each syllable of a word type (and as a consequence the percentages) might not add up exactly to the total because of the presence of occasional errors in the corpus which have remained in the final analysis (this is the case for example of words with no stress marked by mistake). For ease of comparison, the results of the corpus analysis are already paired with those of the nonce word experiment.

A chi-square test has been performed for each condition, comparing the results of the experiment with those of the corpus analysis. If the difference between the two sets of results is statistically highly significant ($p < .001$) the row for that condition is highlighted in dark blue, while if the difference is statistically marginally significant ($p < 0.05$) the row for that condition is highlighted in light blue. The LLL condition is also always highlighted in grey. Since the results of the experiment and of the corpus analysis are expected to be similar, for each condition, the difference between the two analyses is expected not to be statistically significant. For some conditions containing a heavy syllable, the words retrieved from the corpus were too few to make a reliable comparison with the respective conditions in the experiment through a statistical analysis. These conditions, for which the chi-square test was thus not performed, are highlighted in red.
Overall, out of 3822 words with the same syllable structure that were used in the nonce word experiment, 2019 were 2-syllable words, 1469 were 3-syllable words and 334 were 4-syllable words. The general distribution of stress in 3-syllable words is reported in figure (6).

The comparison of the results of the experiment and the corpus analysis for the 2-syllable words is given in table (32), the comparison of the results for the 3-syllable words is given in table (33) and the comparison of the results for the 4-syllable words is given in table (34). In each table, in the 'Example' column of each condition, the first word is an example of a nonce word, the second word is an example of a real word with stress on the syllable which was stressed most often in the corpus in that condition.

Figure (6). Distribution of stress in 3-syllable words in German.

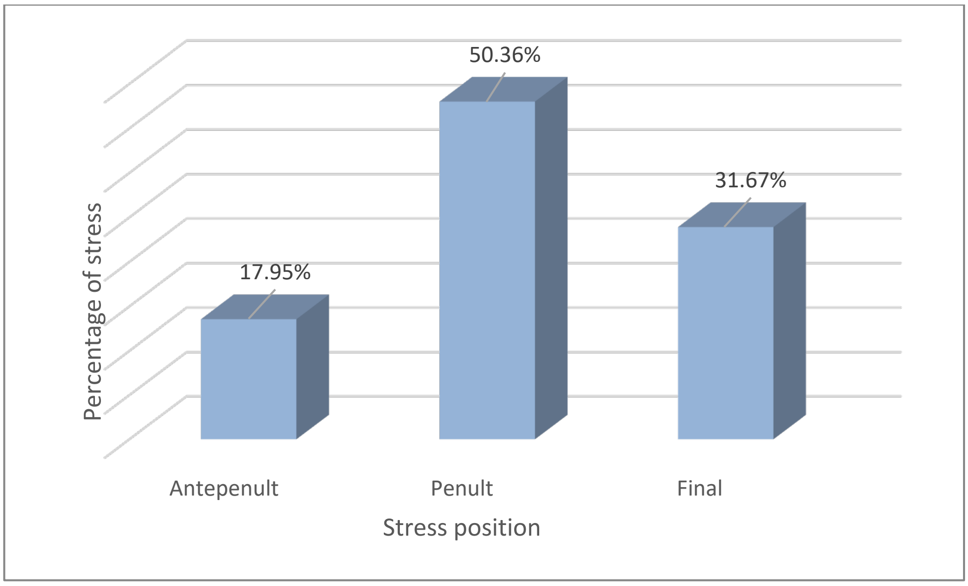

Table (32). Comparison of the results of the experiment and the corpus analysis for the 2-syllable words.

				Experiment		Corpus	
Condition	**Type of heavy syllable**	**Structure**	**Example**	**Stress on P**	**Stress on F**	**Stress on P**	**Stress on F**
1.	[None]	LL	Ba.fa Kí.no	100% (120)	0% (0)	99.31% (436)	0.68% (3)
2.	Coda	HL	Man.ka Bír.ne	100% (85)	0% (0)	98.89% (268)	1.10% (3)
3.		LH	Se.lop Fét.tig[100]	68.23% (58)	31.76% (27)	82.04% (1074)	17.95% (235)
3b.		LH (without suffixes)	Se.lop Ká.bel	68.23% (58)	31.76% (27)	77.46% (808)	22.53% (235)

Table (33). Comparison of the results of the experiment and the corpus analysis for the 3-syllable words.

				Experiment			Corpus		
Con.	**Type of heavy syllable**	**Struct.**	**Example**	**Stress on A**	**Stress on P**	**Stress on F**	**Stress on A**	**Stress on P**	**Stress on F**
4.	[None]	LLL	Te.bo.to Ba.ná.ne	5.11% (9)	93.75% (165)	1.13% (2)	6.7% (12)	93.29% (167)	0% (0)

[100] Note that double consonants at the orthographic level do not represent geminates, which do not exist in German.

5.	Coda	HLL	Pal.sa.ra Hyp.nó.se	5.83% (7)	94.16% (113)	0% (0)	7.89% (6)	92.10% (70)	0% (0)
6.		LHL	Wa.tan.ka Se.kún.de	0.83% (1)	94.16% (113)	5% (6)	2.5% (1)	97.5% (39)	0% (0)
7.		LLH	Bo.go.rok Po.li.tík	28.94% (33)	18.42% (21)	52.63% (60)	33.10% (195)	32.25% (190)	34.63% (204)
7b.		LLH (without suffixes)	Bo.go.rok fa.vo.rít	28.94% (33)	18.42% (21)	52.63% (60)	35.49% (159)	18.97% (85)	45.53% (204)
8.	Double Coda	LLH	Re.lo.ponk Do.ku.mént	15.12% (18)	6.7% (8)	78.15% (93)	6.89% (8)	6.03% (7)	87.06% (101)
9.	Falling Diph.	HLL	Lau.fa.ka Pau.schá.le	6.41% (5)	92.3% (72)	1.28% (1)	44.44% (4)	44.44% (4)	11.11% (1)
10.		LHL	To.pau.fo Po.sáu.ne	2.46% (2)	95.06% (77)	2.46% (2)	0% (0)	100% (3)	0% (0)
11.		LLH	Bi.fu.rai Po.li.zéi	9.63% (8)	10.84% (9)	79.51% (66)	0% (0)	0% (0)	100% (82)
12.	Vowel Length	HLL	Feh.ro.fo [none]	7.27% (4)	90.90% (50)	1.81% (1)	0% (0)	0% (0)	0% (0)
13.		LHL	Ga.sah.ra Ga.lée.re	0% (0)	96.36% (53)	3.63% (2)	0% (0)	100% (1)	0% (0)
14.		LLH	Lo.fo.reh Ko.lo.níe	12% (6)	22% (11)	66% (33)	8% (2)	0% (0)	92% (23)
15.	Vowel sonority	HLL	Ma.fi.ni [none]	3.40% (3)	95.45% (84)	1.13% (1)	0% (0)	0% (0)	0% (0)
16.		LHL	Gu.ra.pi [none]	2.24% (2)	95.50% (85)	2.24% (2)	0% (0)	0% (0)	0% (0)
17.		LLH	Pi.lu.na Tú.ni.ka	11.11% (10)	86.66% (78)	2.22% (2)	100% (1)	0% (0)	0% (0)
18.	Double onset	HLL	Fra.la.pa Gra.ná.te	7.40% (6)	92.59% (75)	0% (0)	4.54% (2)	95.45% (42)	0% (0)
19.		LHL	Pa.kra.fa Ma.tró.se	8.53% (7)	91.46% (75)	0% (0)	0% (0)	100% (24)	0% (0)
20.		LLH	Ne.po.fro Kó.li.bri	10% (8)	80% (64)	10% (8)	100% (1)	0% (0)	0% (0)
21.	Triple onset	HLL	Spre.to.bo Stra.té.ge	23.45% (19)	76.54% (62)	0% (0)	0% (0)	100% (3)	0% (0)
22.	Coda +	LHH	Me.rol.pok	17.14%	27.14%	55.71%	17.26%	56.54%	26.19%

	coda		ge.wál.tig	(12)	(19)	(39)	(29)	(95)	(44)
22b.		LHH (without suffixes)	Me.rol.pok Ka.lén.der	17.14% (12)	27.14% (19)	55.71% (39)	12.28% (14)	49.12% (56)	38.59% (44)
23.	Falling diph. + coda	LHH	Le.rau.nof The.sáu.rus	7.24% (5)	55.07% (38)	37.68% (26)	0% (0)	100% (6)	0% (0)
24.	Double onset + coda	LHH	Sa.tra.gal lu.kra.tív	33.33% (24)	22.22% (16)	44.44% (32)	22.22% (10)	26.66% (12)	51.11% (23)
25.	Vowel length + coda	LHH	Pa.lah.ran ko.díe.ren	25.67% (19)	36.48% (27)	37.83% (28)	0% (0)	100% (97)	0% (0)

Table (34). Comparison of the results of the experiment and the corpus analysis for the 4-syllable words.

				Experiment			**Corpus**		
Con.	**Type of heavy syllable**	**Struct.**	**Example**	**Stress on A**	**Stress on P**	**Stress on F**	**Stress on A**	**Stress on P**	**Stress on F**
26.	[None]	LLLL	Me.po.ro.to Li.mo.ná.de	4.54% (4)	95.45% (84)	0% (0)	1.20% (1)	98.79% (82)	0% (0)
27.	Coda	LHLL	Ba.lan.ka.sa De.fen.sí.ve	3.37% (3)	96.62% (86)	0% (0)	13.33% (2)	86.66% (13)	0% (0)
28.		LLHL	Ki.fu.pun.ki Ka.ta.kóm.be	0% (0)	100% (87)	0% (0)	0% (0)	100% (14)	0% (0)
29.		LLLH	Se.ro.go.pot ka.pi.tá.lisch	1.20% (1)	40.96% (34)	57.83% (48)	7.92% (16)	51.48% (104)	40.59% (82)
29b.		LLLH (without suffixes)	Se.ro.go.pot fi.gu.ra.tív	1.20% (1)	40.96% (34)	57.83% (48)	3.87% (5)	32.55% (42)	63.56% (82)
30.	Double coda	LLLH	Di.lu.no.rast Me.di.ka.mént	2.46% (2)	22.22% (18)	75.30% (61)	5.26% (1)	0% (0)	94.73% (18)
31.	Falling diph.	LHLL	Ri.fau.li.ri [none]	2.43% (2)	97.56% (80)	0% (0)	0% (0)	0% (0)	0% (0)
32.		LLHL	Me.so.lau.po Me.no.páu.se	0% (0)	100% (83)	0% (0)	0% (0)	100% (2)	0% (0)
33.		LLLH	Ga.fa.na.rau [none]	1.23% (1)	17.28% (14)	81.48% (66)	0% (0)	0% (0)	0% (0)

10.4 Discussion of results

The results for the 3-syllable words will be discussed first, since this is the word type that comprises the full 3-syllable window for stress in German without any possible effect of full parsing. Subsequently, the results for the 2-syllable words will be discussed and finally the results for the 4-syllable words.

The general distribution of stress in 3-syllable words in the corpus (irrespective of word structure), reported in table (33), indicates that stress generally tends to fall mostly on the penultimate syllable (50.36%) followed by the final syllable (31.67%), followed by the antepenultimate syllable (17.95%). More specifically, looking at the LLL condition (4.) in which no heavy syllable is present, it can be seen that stress falls predominantly on the penultimate syllable both in the experiment (93.75%) and in the corpus (93.29%), so that both analyses confirm that the default position of stress in German is on the penultimate syllable. The results of the chi-square test indicate that the difference between the two analyses is not significant ($p = 0.299$), suggesting a close relationship between the results of the experiment and the corpus analysis.

When looking at all the other conditions for 3-syllable words, i.e. all the conditions containing at least one heavy syllable (5.-25.), some general observations can be made.

Firstly, for the conditions highlighted in red (10 out of 21), the number of items in the corpus were too few to be reliably compared with the items of the experiment through a statistical analysis. This was due to the fact that, in German, non-compound words of 3 syllables are mostly words of Latin origin, which comprise only a minority of the German lexicon, so that in many cases there are very few 3-syllable words with the exact syllable structure investigated in the nonce word experiment. In these cases there is often a clear mismatch between the experiment and the corpus but due to the small number of items involved such mismatch cannot be really deemed of significance. These conditions are: the HLL and LHL conditions with a heavy syllable with a falling diphthong (CVG) (9.-10.), all the conditions (HLL, LHL, LLH) with a heavy syllable with a sonorous vowel (C/a/) (15.-17.), the HLL and LHL conditions with a long vowel (CVV) (12.-13.), the LLH condition with a heavy syllable with a double onset (CCV) (20.), the HLL condition with a heavy syllable with a triple onset (CCCV) (21.) and the LHH condition with a penultimate heavy syllable with a falling diphthong plus a final heavy syllable with a consonant in the coda (CV.CVG.CVC) (22.).

For example, for the HLL condition with a falling diphthong (CVG) (9.), the corpus contained only 9 items, which were stressed 44% of the times on the antepenult (4 items), 44% of the times on the penult (4 items) and 11.11% of the times on the final (1 item), while in the same HLL condition in the experiment stress falls 6.41% of the times on the antepenult, 92.3% of the times on the penult and 1.28% of the times on the final.

However, these conditions with few items in the corpus can still be of interest, since they reveal how the influence of syllable weight observed in the experiment seems to operate independently of the real lexicon. For instance, with respect to the LHH condition with a penultimate syllable with a falling diphthong plus a final syllable with a consonant in the coda (CV.CVG.CVC) (23.), it is possible to see that the corpus contains very few items of this type (only 7). On this basis, one might think that, if the speakers generalize the stress pattern from the lexicon, not having many items from which they could retrieve a specific stress pattern they might choose, in nonce words, to simply place stress overwhelmingly on the penultimate default position (90% or more, as in the LLL condition). However, this does not seem to be the case, since in the LHH condition (23.) in the experiment stress is placed 7.24% of the times on the light antepenult, 55.07% of the times on the heavy penult (CVG) and 37.68% of the times on the heavy final (CVC), suggesting that the distribution of stress in this condition is determined uniquely by the structure of the syllables, in this case the penult and the final which count as heavy and attract most of the stress, and not by the corresponding real words in the lexicon, that are extremely scarce.

With respect to all the other conditions with a heavy syllable for which it was possible to make a direct comparison between the experiment and the corpus (i.e. those not highlighted in red), it can be seen that, for most conditions, the syllable which is most frequently stressed in the experiment is also the syllable which is most frequently stressed in the corpus, suggesting a possible relationship between the two.

More specifically, for the conditions with a final light syllable (HLL, 5. and LHL, 6.) in which the corpus contained enough words to make a comparison with the experiment, it can be seen that, for both conditions, both in the experiment and in the corpus stress is placed most frequently on the penult and the difference between the two analysis is not statistically significant, so that also the corpus analysis confirms the results of the experiment for the HLL and LHL conditions.

Also in the condition with a final superheavy syllable with two consonants in the coda (LLH-CVCC) (8.), it can be seen that stress falls most frequently on the final heavy syllable in both the experiment and the corpus and the difference between the results of the two analyzes is not significant ($p = 0.122$), indicating that the results of the corpus analysis confirm that a final heavy syllable with two consonants in the coda attracts stress to a high degree (around 80%), as was found in the nonce word experiment.

However, looking at all the other conditions with a final heavy syllable (LLH or LHH) with either a diphthong (CVG, 11.), a long vowel (CVV, 14.) or a consonant of the coda (CVC) (7., 22., 24., 25.) it can be seen that the results of the nonce word experiment and of the corpus analysis match only in the case of the condition with a heavy penult with a double onset + a heavy final with a consonant in the coda (CV.CCV.CVC) (.24), since this is the only condition in which stress falls most frequently on the same syllable in both the experiment and the corpus and in which the difference between the two analyzes is not statistically significant ($p = 0.435$). More specifically in condition 24., in both the experiment and the corpus stress falls most frequently on the final CVC syllable, (44.44% and 51.11% respectively) and only moderately on the penultimate syllable with a double onset (CCV) confirming the results of the experiment that indicated an influence of a final heavy syllable with a consonant in the coda, while suggesting that penultimate syllable with a double onset (CCV) does not attract stress in comparison to the baseline LLH-CVC condition.

However, in the case of all the other conditions with a final heavy syllable (LLH) (7., 11.,14., 22., 25.) the relationship between the results of the experiment and of the corpus analysis is less clear.

More specifically, looking at the condition with a final heavy syllable with a consonant in the coda (LLH-CVC) (7.), it can be seen that, while in the experiment the most frequently stressed syllable is the heavy final (52.63%), in the corpus the percentage of stress on the three syllables of the word is very similar, with the final heavy syllable being only slightly more stressed than the other two syllables (34.63% of stress on the final *vs* 33.10% and 32.25% of stress on the antepenult and penult respectively) and the difference between the two analyzes turns out to be statistically highly significant ($p < .001$). However, looking at the words in the corpus within this condition, it has been noted that many of them are morphologically complex words, more specifically they are words that contain some kind of derivational suffix. One hypothesis to explain the mismatch between the results of the experiment and the corpus might be thus that, in the corpus, the stress patterns determined by syllable weight are somewhat obscured by the influence of suffixes which might override the stress assignment rules determined by syllable weight alone. In order to test this hypothesis, a second corpus analysis for condition 7. has been run, in which words with a final suffix are taken out of the analysis. In order to establish exactly what kinds of word endings count as suffixed, the following criteria were used: an ending is counted as a suffix if it is a productive morpheme, e.g. -*ung*, which forms nouns from verbs, as in *Entdeckung* ‘discovery’ from *entdecken* ‘to discover’ or, more generally, an ending is counted as a suffix if it is attached to a stem which represents an unbound morpheme, such as -*isch* in *Japanisch* ‘Japanese’ from *Japan* ‘Japan’. Under these criteria, an ending such as -*iv*, is not counted as a suffix, since it is not attached to an unbound morpheme, although it still represents a relatively frequent ending forming adjectives in German words of non-Germanic origin, such as *positiv* ‘positive’, *relativ* ‘relative’, *kognitiv* ‘cognitive’ etc. Looking at the results of the new analysis for LLH-CVC without suffixed words (7b.), it can be seen that the percentages of stress on the three syllables in the corpus align with those found in the nonce word experiment, i.e. in the corpus stress falls most frequently on the final (45.53%) followed by the antepenult (35.49%), followed by the penult (18.97%) and the difference with the results of the experiment does not turn out to be statistically significant ($p = 0.345$). The results of this second analysis support the hypothesis that the relationship between the stress patterns found in the experiment and those found in the corpus is based mostly (or perhaps exclusively) on morphologically simple words, i.e. words that do not contain any suffixes and are thus monomorphemic (at least from the point of view of the speakers).

These results would suggest that, under the hypothesis that speakers generalize the stress patterns found in the real lexicon to the nonce words, they likely access only the stress patterns in the lexicon associated with morphologically simple words, disregarding morphologically complex words in which stress patterns are influenced by the suffixes. Under the opposite hypothesis, i.e. that the stress patterns in the nonce words represent the stress rules underlying the speaker’s competence which have been applied to the real lexicon through the history of the language, these results suggest that the stress algorithm based on syllable weight is applied only to morphologically simple words, while the stress rules of morphologically complex words operate separately through the application of the suffixes.

With respect to the condition with a final heavy syllable with a falling diphthong (LLH-CVG) (11.) it can be seen that in both the experiment and the corpus stress falls most frequently on the final heavy syllable, confirming the strong influence of a final heavy syllable with a falling diphthong. However, in the experiment stress is placed on the final syllable 79.51% of the times, being placed also somewhat on the antepenult (9.63%) and penult (10.84%), while in the corpus stress is placed exclusively on the final syllable (100%) and the difference between the two analysis is statistically highly significant ($p < .001$). It has to be noted, however, that in this condition all the words in the corpus were morphologically complex words with the suffix *-ei*, a suffix which can form nouns from other nouns, such as *Malerei* ‘painting’ from *Maler* ‘painter’ (but which can also appear as an ending in monomorphemic words, such as in *Polizei* ‘police’). For this reason, it might be assumed that, in this condition, the stress assignment rules in the speakers’ competence are visible only in the results of the nonce word experiment, while in the corpus the assignment of stress overwhelmingly on the final is due to the stress assignment rules associated with the specific suffix *-ei.*

With respect to the condition with a final heavy syllable with a long vowel (LLH-CVV) (14.), it can be seen that the results are similar to those of the LLH-CVG condition just described, in that in both the experiment and the corpus stress falls most frequently on the heavy final (66% and 92% respectively), but in the experiment stress falls somewhat also on the antepenult (12%) and penult (22%), while in the corpus stress falls overwhelmingly on the final (with only 8% of stress on the antepenult and 0% on the penult) and the difference is statistically significant (although only marginally, p = 0.027). Looking at the words in the corpus for this condition, it can be seen that they are almost all words with the ending -*ie* (representing a long vowel /i:/). Unlike -*ei* in the LLH-CVG condition, -*ie* is likely not analyzed as a suffix in the speakers' competence, since it is not attached to an unbound morpheme; rather, words with this ending are likely to be interpreted as monomorphemic by the speakers, such as *Parodie* 'parody' or *Kolonie* 'colony'.[101] One interpretation of these data could be that the results of the experiment and the corpus for this condition should still be considered comparable, since the difference is statistically significant only by a very low margin (p = 0.027) and might be due to a size effect related to the low number of items in both analyzes. To support this hypothesis there is the fact that, as explained in section (10.2) above, for the LLH-CVV condition in the corpus only words with graphemes that clearly represent long vowels were included, so that it is likely that, in this condition, the corpus might lack some words with long vowels which are not represented at the orthographic level. These missing words might perhaps be words associated with stress on the antepenult or penult, so that, if included, they might reduce the difference between the two analyzed, both in terms of percentages in the distribution of stress and in terms of statistical significance. Overall, as already mentioned in section (10.2), it has to be considered that the difficulty in establishing precisely which vowels are long in German makes the results of this condition inevitably less reliable than the results of the other conditions, in which the relevant syllable structure can be clearly represented both in the nonce word experiment and in the corpus.

With respect to the HLL and LHL conditions with a heavy syllable with a double onset (CCV) (18.-19.), it can be seen that both in the results of the experiment and in those of the corpus stress falls most frequently on the penult and the difference between the two analyses is not statistically significant, so that the corpus analysis confirms the results of the experiment.

With respect to the condition with both a penultimate and final syllable with a consonant in the coda (CV.CVC.CVC) (22.), it can be seen that, while in the experiment stress falls most frequently on the final (55.71%), in the corpus stress falls most frequently on the penult (56.54%) and the difference between the two analyses is statistically highly significant (p < .001). One explanation for the discrepancy between the two analyses might be that, as was the case of the

[101] A couple of words in this condition have the ending -*ee* (also representing a long vowel /i:/), such as *Komitee.* These words are also likely to be analyzed as monomorphemic by the speakers.

LLH-CVC condition (7.), CV.CVC.CVC words in the corpus might contain some suffixes which increase the percentage of stress on the penultimate syllable in comparison to the nonce word experiment, in which the penultimate syllable is stressed only 27.14% of the times. In order to see whether in the CV.CVC.CVC condition the influence of morphology might cause an increase of the percentage of stress on the penult in comparison to the nonce word experiment, all suffixed words of this condition in the corpus were taken out of the analysis. The criteria for establishing which word endings count as suffixes is the same used for condition (7.). For the CV.CVC.CVC the words taken out in the new analysis were mostly words with suffixes -*isch* e -*ung* and -*ig*, plus some words with the suffixes -*in* (forming female nouns) and -*chen* (forming diminutives). As can be seen from (22b.), in this new analysis the most frequently stressed syllable remains the penult, however there is still an improvement in the results, since the percentage of stress on the final increases from 26.19% of the analysis with the suffixed words to 38.59% of the analysis without the suffixed words. Furthermore, although the difference between of the results of the experiment and the corpus remains significant, the p-value increases from $p < .001$ to $p = 013$. On this basis, it could be argued that, as was the case of condition the LLH-CVC condition (7.), also in the CV.CVC.CVC condition (22.) morphology plays a role in the corpus in determining the stress patterns, while in the experiment the stress patterns are supposedly determined uniquely by the stress algorithm based on syllable weight.

Concerning the condition with both a penultimate syllable with a long vowel and a final syllable with a consonant in the coda (CV.CVV.CVC) (25.), it can be seen that there is a clear mismatch between the results of the experiment, in which stress is placed most frequently on the final syllable (37,83%), and those of the corpus in which stress falls exclusively on the penultimate syllable (100%). As was the case for the LLH-CVV condition (14.), this mismatch could be attributed to the fact that the CV.CVV.CVC condition in the corpus contained only words whose long vowels were clearly represented at the orthographic level through grapheme clusters such as <ah>. Since vowels represented by such grapheme clusters are mostly stressed in German, it is to be expected that in words of the CV.CVV.CVC condition in the corpus stress should fall most frequently (or exclusively) on the penult. It is thus likely that the German lexicon might contain also other words with an CV.CVV.CVC structure in which stress falls also on the antepenult or final, bringing the stress patterns found in the real lexicon closer to those of the nonce word experiment.[102]

[102] The words of the CV.CVV.CVC condition in the present corpus analysis were all words ending in -*ieren* or -*ierung* (from -*ieren* + -*ung*). -*ieren* is a word ending that is found mostly in German words of non-Germanic origin (mostly of Latin origin), which are, for the most part, likely to be interpreted as monomorphemic by the speakers, such as

I will now turn to discuss the results of the 2-syllable words.

Looking at table (32), it is possible to see that for all three conditions tested in 2-syllable words, i.e. LL (1.), HL (2.) and LH (3.), in which the heavy syllable contains a consonant in the coda (CVC), there is a good match between the results of the experiment and the corpus, since for all conditions the most frequently stressed syllable in the experiment, i.e. the penult, is also the syllable stressed most often in the corpus. In the case of the LL (1.) and HL (3.) conditions, the difference between the experiment and the corpus is not statistically significant (p = 0.363 and p = 0.330, respectively), confirming in both analyses the default position of stress on the penult in these two types of word.

However, in the LH condition, although stress falls mostly on the penult in both the experiment and the corpus (68.23% and 82.04%, respectively), the difference is statistically significant (p = 0.002). However, as was the case for the LLH-CVC (7.) and the CV.CVC.CVC (22.) conditions, it might be possible that also in the LH condition the higher percentage of stress on the penult in the corpus with respect to the experiment is due to the presence of some suffixes. In order to test this hypothesis, a new analysis has been carried out taking out all suffixed words. Indeed, the LH condition contained many words with different suffixes, such as *-ung*, *-isch*, *-en* or *-ig*. As can be seen from the new analysis for the LH condition (3b.), by deleting all suffixed words the percentage of stress on the penult decreases from 82.04% to 77.46%, and the difference with the results of the experiment turns out not to be significant (although only by a low margin, p = 0.053). This second analysis confirms that the results of the corpus and the experiment for the LH condition are comparable.

In the case of the nonce word experiment, the tendency for LH to be stressed more frequently on the light penult than on the final CVC syllable, which was found instead to attract stress in 3- and 4-syllable words with the same structure, was explained in chapter (7) as a tendency to achieve full parsing of the word in a disyllabic trochaic foot of the (Ĺ H) type instead of building a bimoraic trochee on the final heavy syllable and leaving the first syllable unparsed, as in L(H́). Indeed, a vast majority of real words in German have a disyllabic structure with stress on the first syllable, in which initial stress cannot (only) be attributed to the influence of specific morphological structures, such as stress-repelling suffixes, e.g. *Dóppel*, *Hórror*, *Bíschof*, *Lógik,* suggesting that this tendency to fully parse a disyllabic word might have occurred historically in the real lexicon as well.

Finally, I will discuss the results of the 4-syllable words.

passieren 'happen', so the high percentage of stress on the penult cannot be attributed to a specific stress-assigning rule associated with this ending(s).

Looking at table (34), it is possible to see that, first of all, the LLHL condition with a heavy penult with a consonant in the coda (CVC) (28.), as well as all the conditions with a heavy syllable with a falling diphthong (CVG) (31.-33.) had too few words in the corpus analysis, so that it was not possible to make a meaningful comparison with the corresponding conditions in the nonce word experiment.

With respect to the LLLL condition (26.), stress falls most frequently on the penult in both the experiment and the corpus and the difference is not statistically significant, confirming the default position of stress on the penult also in 4-syllable words.

With respect to the LLLH condition with a heavy syllable with a consonant in the coda (CVC) (29.), this is the only condition in the 4-syllable words that shows a mismatch between the experiment and the corpus, in that stress falls mostly on the final heavy syllable in the experiment (57.83%) (as was also the case for the 3-syllable word with a final CVC syllable) but not in the corpus, in which stress falls mostly on the penult (51.48%). As was the case for the corresponding conditions in 2- and 3-syllable words (3. and 7.), these results might be due to the presence of some suffixed words, that cause an increase of stress on the penult in comparison to monomorphemic words. In order to test this hypothesis, an alternative analysis was carried out taking out all the suffixed words, which were mostly words containing the suffix -*isch*, such as *medizinisch* 'medical' from *Medizin* 'medicine'. As can be seen in condition 29b., in this new analysis stress in the lexicon falls on the final 63.56% of the times *vs* 57.83% of the times in the experiment and the difference between the two analyses does not turn out to be significant, confirming the influence of a final CVC syllable in 4-syllable words also in the real lexicon.

Finally, with respect to the LLLH condition with a final heavy syllable with two consonants in the coda (CVCC) (30.), it can be seen that the results of the experiment and of the corpus match well in that the final syllable is stressed most of the times in both analyzes (75.30% and 94.73% respectively) and the difference is not statistically significant, confirming also in the corpus that a final CVCC must be considered a superheavy syllable.

With respect to the question of the possibility to achieve full parsing in 4-syllable words, in the nonce word experiment the results of LLLL, LHLL and LLHL were interpreted as showing no effect of parsing, since stress was most frequently on the penult to the same degree as in the corresponding 3-syllable words (see chapter 7). However, LLLH was interpreted as showing a tendency to achieve full parsing, since stress was placed on the penult more often than in LLH, irrespective of the final heavy syllable. Overall, since the results of the corpus analysis are not statistically different from those of the nonce word experiment (once the influence of morphology is accounted for), it can be concluded that also the results of the experiment confirm the effect of parsing only in the LLLH condition.

In conclusion, the results of the corpus analysis mostly corroborate the results of the nonce word experiment. However, in some conditions the words in the corpus were too few to make a reliable comparison with the corpus. These conditions are still of interest because they suggest how the stress assignment algorithm determined by syllable weight seems to operate independently of the patterns found in the real lexicon.

In the case of words with a final CVC syllable, it has also been seen that the presence of some suffixes might override the stress-assignment algorithm determined by syllable weight, causing a higher percentage of stress on the penult in the corpus in comparison to the experiment. This effect was not seen in other conditions, most notably in the conditions with a final light syllable, since these conditions did not contain any suffix that, from the point of view of the speakers, would make the word morphologically complex.

One further factor that was found to cause a mismatch between the result of the experiment and of the corpus analysis is the fact that it was not possible to fully control for vowel length, since in German it is not possible to determine with certainty in all cases whether a specific vowel in a specific position should count as long or short. As already mentioned above, the results of the corpus analysis with respect to vowel length should not be considered as reliable as in the case of the results for all the other conditions, in which it was always possible to find in the lexicon all the words with the precise syllable structures that were used in the nonce word experiment.

Overall, if the external influence of morphology and the possible influence of vowel length are taken into account, one may conclude that the corpus analysis confirms the results of the experiment.

With respect to the single word types, in the 3-syllable words, the default position of stress in German can be confirmed to be on the penultimate syllable, while final CVC or CVV syllables are heavy and attract stress and final CVCC or CVG syllables are superheavy, i.e. they attract stress more than a final CVC or CVV. A penultimate CVC, CVV and CVG syllable in LHH tends to shift stress from the final to the penult.

In 2-syllable words, in both the experiment and the corpus there is a tendency to place stress on the first syllable, even when the final is heavy, allowing full parsing of the word into a disyllabic trochee.

In 4-syllable words, the corpus analysis confirms that an effect of full parsing is present only in the LLLH condition.

Part 2

The acoustic correlates of primary and secondary stress in Italian and German

11 The acoustic correlates of stress

This chapter gives an overview of the main acoustic correlates of primary and secondary stress among the world's languages. The acoustic correlates of stress in a language can be analyzed both from a production and perception point of view. In this chapter, the main focus will be on production studies, since the chapter concerning the acoustic correlates of stress in Italian and German and the relative experiments will also involve production experiments.

Among the world's languages, a great variety of acoustic correlates of stress have been identified. The main ones include: duration, intensity, fundamental frequency (F0), formant frequencies (mainly F1 and F2) and spectral tilt.

Duration usually refers to vowel duration, and it is probably the correlate of stress which has been found to play the most important role in the majority of languages (see Gordon & Röttger 2017's survey below), such as in English, where although also F0 and intensity also seem to play a role, duration seems to be the major correlate of stress (Bettagere 2010).

Duration can alternatively be measured as the duration of the entire syllable or of single segments of the syllable, such as the consonants in the onset or in the coda. For example, Fant *et al.* (1991), in a study focused on duration in French, Swedish and English, found that stressed and unstressed syllables in all three languages differed in vowel duration and that in English also the consonants in the onset and in the coda were lengthened in stressed syllables, while in French this effect was stronger for the consonants in the onset, whereas in Swedish it was stronger for the consonants in the coda.

Intensity is usually measured as the mean intensity of the vowel, but other types of measures include for example the peak of intensity or the midpoint of intensity within a vowel (e.g. Okobi 2006, Bettagere 2010 for English).

Fundamental frequency (F0) can also be measured in a variety of ways, such as mean F0, as the peak of F0 within a vowel or at the vowel midpoint. Other measures also include calculating the variation of F0 within the vowel, such as analyzing the slope of F0 or its standard deviation.

Although F0 has been found to be a correlate of stress in some languages (e.g. Adisasmito-Smith & Cohn 1996, for Indonesian), it still remains a parameter whose reliability as correlate of stress is often difficult to establish, since it is often conflated with sentence accent by the fact that stressed syllables, when accented, tend to function as anchor points for the pitch accents related to the intonational contour of a sentence. This can be seen specifically when comparing stressed and unstressed vowels in accented and unaccented conditions. For example, a series of studies on Spanish show that a pitch increase on the stressed vowel is present in accented conditions but not in unaccented conditions (i.e. in parenthetical utterances) (Ortega-Llebaria & Prieto 2007, Ortega-Llebaria 2006). A study of English (Okobi 2006) analyzed different acoustic parameters in words in focus condition and in two non-focus conditions and found that duration and spectral tilt were significant correlates in all conditions, but F0, peak intensity and amplitude of the first harmonic were found to be significant only in the focus condition. Furthermore, it seems possible also for other parameters besides F0 to be influenced by the accented or unaccented condition. For example, duration was found to be influenced by the accented/unaccented conditions in English and Dutch (e.g. Langeveld & Turk 1999), as well as intensity in Swedish (Heldner 2002). These differences should thus be taken into account when comparing studies in which stress is measured in an accented condition with studies in which stress is measured in an unaccented condition.

Formant frequencies, usually of the first two formants, F1 and F2, are measured in order to analyze how vowel quality changes in stressed and unstressed position. Formant frequency measurements are based on the assumption that an unstressed vowel will undergo a certain degree of centralization, so that its formant values will tend to converge towards those of a central vowel (a schwa), while the formant values of the same vowel under stress will tend to reflect a more peripheral articulation of the vowel. As can be expected, the effects of changes in formant values emerge more clearly in languages in which unstressed vowels undergo phonological vowel reduction, such as in English (Lunden 2017). However, formant frequencies have been proved to be reliable correlates of stress also in languages whose phonological system does not involve vowel reduction, such as in Spanish, in which for example, according to one study, the vowel [o] tends to become more centralized when it is found in unstressed position (Ortega-Llebaria & Prieto 2007).

Spectral tilt refers to an acoustic parameter that defines how intensity varies as a function of frequency. More specifically, intensity tends to be lower at higher frequencies in comparison to lower frequencies. This drop in intensity at higher frequencies is usually found to be steeper in unstressed syllables than in stressed syllables, the latter of which tend to retain more of the high-frequency energy. Spectral tilt is thus usually calculated as the difference or ratio between the intensity of two frequency bands in the spectrum. For example, Plag *et al.* (2011) calculated it as the difference between the mean intensity of two frequency bands, the first ranging from 1000 to 4000 Hz (B1) and the second ranging from 0 to 1000 Hz (B2), i.e. B1 - B2, measured in db SPL.[103] Other measurements include the difference between the intensity of the first and second harmonics, H1-H2 (Kakouros *et al.* 2017). Studies in which some kind of measurement of spectral tilt was found to be a correlate of stress include Sluijter & Van Heuven (1996) and Campbell & Beckam (1997) for

[103] In Plag *et al*. (2011)'s study, spectral tilt is called 'spectral balance'.

Dutch (in the latter spectral tilt was a reliable correlate only in accented condition), Crosswhite, K. (2003) for Polish, Macedonian and Bulgarian and Ortega-Llebaria & Prieto (2007) for Spanish.

With respect to all the above mentioned acoustic parameters, from a meta-analysis of 110 studies on 75 languages from a variety of language families (Gordon & Röttger 2017) it emerges that the most investigated parameters, from most investigated to least investigated, are (in parenthesis the number of studies): duration (85), F0 (56), intensity (49), formants (29) and spectral tilt (17). When controlling for the number of studies in which one or more parameters were considered, the acoustic parameter that turns out to be a reliable correlate of stress the majority of the times is duration (90%), followed by formants (86%), spectral tilt (84%), intensity (75%) and F0 (73%).

The variability in the significance of certain parameters as acoustic correlates of stress among the world's languages can also be attributed to the influence of various external variables.

For instance, one variable that can be relevant when analyzing the correlates of stress is related to the position of the stressed syllable within a word. Some studies reported differences in the realization of one or more correlates of stress depending on the position of the stressed syllable. For example, in Spanish, differences in duration were found with respect to the final and penultimate stressed syllables, with final syllables having generally longer duration (Ortega-Llebaria & Prieto 2007). Okabi (2006) found that, in 2-syllable real words and nonce words in English, the difference in duration between the stressed and unstressed syllables tended to be higher when stress was on the final syllable in comparison to when stress was on the first syllable.

Another variable that might influence the correlates of stress might be related to the position of the target word within the wider prosodic context, such as whether a word is found before a pause or not. In Fant *et al.* (1991) it was found that durational differences of stressed and unstressed vowels and consonants in French differed between prepausal and non-prepausal location, with the former having on average higher duration.

One other variable that has been reported as having an influence on the acoustic correlates of stress is speaking style. Eriksson & Heldner (2015), analyzed the acoustic correlates of stress in English, namely F0, F0 variation, duration and spectral emphasis,[104] across three different speaking styles, i.e. wordlist reading, phrase reading, spontaneous speech. With respect to primary stress, the authors found that F0, F0 variation (only marginally), duration and spectral emphasis were all significant correlates of stress but that they also differed with respect to speaking style. With respect to F0, the difference between stressed and unstressed vowels was found to be higher in wordlist

[104] Spectral emphasis in this study represents a parameter similar to spectral tilt and it is calculated by the authors as the difference in dB between the Sound Pressure Level (SPL) of the full spectrum and the SPL of F0 in each segment.

reading and phrase reading in comparison to spontaneous speech. F0 variation was found to be larger in wordlist reading in comparison to phrase reading and spontaneous speech. Duration was found to be different across all speaking styles, being higher in wordlist reading than in phrase reading, in which it was in turn higher than in spontaneous speech. Finally, spectral emphasis was found to be higher in spontaneous speech in comparison to wordlist reading and phrase reading.

With respect to secondary stress, as evidenced by Gordon & Röttger (2017)'s survey, it emerges that secondary stress is generally underrepresented in studies on the acoustic correlates of stress, with only 21 studies out of 110 including measurements of possible acoustic correlates of secondary stress. In those cases in which the acoustic correlates of secondary stress are investigated, it turns out that they are usually only a subset of the acoustic correlates of primary stress. However, overall, the acoustic correlates of secondary stress remain elusive in many languages (see, for instance, the case of German in chapter 13). Furthermore, as is the case with primary stress, the identification of the acoustic correlates of secondary stress is complicated by the influence of the external variables mentioned above, such as the presence of an accent or variability related to speakers.

For example, in the same study on English already mentioned (Eriksson & Heldner 2015), the authors also investigated secondary stress and, among the analyzed parameters, i.e. F0, F0 variation, duration and spectral emphasis, while they found all of them to be significant correlates of primary stress, only duration was found to be a significant correlate of secondary stress, with secondary stressed vowels shorter than primary stressed vowels and longer than unstressed vowels, confirming how the correlates of secondary stress often tend to be only a subset of those that signal primary stress. Spectral emphasis was also found to distinguish secondary stressed vowels from primary stressed vowels, but only for male speakers, suggesting a possible difference in the realization of secondary stress related to sex in the case of this acoustic parameter.

Plag *et al.* (2011) analyzed words with both a primary and secondary stress, that could either have primary stress on the left and secondary stress on the right (e.g. *víolàte*) or primary stress on the right and secondary stress on the left (e.g. *vìolátion*) and found that F0, intensity and spectral balance,[105] but not duration nor pitch slope, were significantly different between the primary stressed vowels and secondary stressed vowels, although the difference was larger for words with primary stress on the left. However, as in the case of many studies on primary stress, also in this study a difference was found between accented and unaccented condition. Namely, differences between the left and right margin of the words emerged more significantly in the accented condition than in the unaccented condition, so that the authors attribute the difference in the acoustic

[105] See above for the specifics of the measurement used.

correlates between the two word margins to the presence of two accents more than to a clear distinction between a primary and a secondary stress. In any case, this study suggests how analyzing words in accented conditions might be crucial for any acoustic correlate of secondary stress to emerge clearly.

In a study on primary and secondary stress in Indonesian on two speakers using reiterated speech (one male and one female) (Adisasmito-Smith & Cohn 1996), the authors found that primary stressed syllables (which are always the penult) were cued by F0 and intensity for both speakers and by duration only for the male speaker. With respect to secondary stress (which is found on the first syllable in 4-syllable and 5-syllable words) they found no effect of F0 for any of the two speakers, while they found an effect of intensity for the female speaker and an effect of duration for the male speaker. Although this study is carried out on only two speakers, it might highlight the possibility of sex as a variable influencing the acoustic parameters of secondary stress.

Overall, both primary and secondary stress can be cued by a variety of acoustic correlates, which in turn can be calculated in many different ways. Of all these correlates, duration seems to be the most relevant to differentiate between primary stressed syllables and unstressed syllables. In the case of secondary stress, its acoustic correlates have been proved difficult to detect clearly and they often emerge only as a subset of the acoustic correlates of primary stress. Finally, both the acoustic correlates of primary and secondary stress can be influenced by a variety of external factors related to the position of the target syllables in the wider prosodic context and to differences related to the single speakers.

12 The acoustic correlates of stress in Italian

12.1 The acoustic correlates of primary stress in Italian

The acoustic correlates of stress in Italian have been the object of different studies, using various methodologies on different Italian varieties, many of which concentrated specifically on vowel duration (Marotta 1985, Faretani & Kori 1985, Hajek *et al*. 2007, Hajek and Stevens 2008, see below for details), while other studies investigated a wider variety of correlates of stress either through production experiments (Bertinetto 1981, Romito 1994, Eriksson 2016) or perception experiments (Bertinetto 1980, Alfano 2006, Sulpizio & McQueen 2012, Caccia *et al.* 2019).

In this chapter, the main focus of discussion will be on production studies, since also the study on the correlates of stress in Italian presented in chapter 14 will consist of a production experiment.

In one of the first comprehensive production studies on stress in Italian, Bertinetto (1981) analyzed duration, F0 and intensity in words with stress either on the antepenult, penult or final (e.g., *cápito* 'I end up', *capíto* 'understood', *capitó* 'it happened'). The words were read in isolation by four native Italian speakers from Turin (North-West). Although Bertinetto's analysis was purely descriptive (no statistical analysis was performed), the results indicated that duration was systematically longer on the stressed syllable in all positions, suggesting that it might be a strong correlate of stress, while intensity and F0 tended to be higher at the left margin of the word, irrespective of stress position.

In a subsequent study, Romito (1994) analyzed duration, intensity, F0 and formant frequencies (F1 and F2) in stressed and unstressed vowels in CV syllables. The target syllables could be found in words with different length (from 2 to 5 syllables), with the stressed syllables in two different positions (penult or final). The study was conducted with speakers from three varieties related to the areas surrounding three different cities, namely Padova (North-East), Reggio Calabria (South) and Napoli (South). The results of Romito's study, which, as in the case of Bertinetto (1981), was mostly descriptive, seemed to in part corroborate Bertinetto's results. More specifically, in all the three investigated varieties, the stressed syllables were found to be always longer than the unstressed ones irrespective of stress position within the word, pointing at duration as a strong correlate of stress in Italian. With respect to intensity, higher intensity seemed to correlate with stressed syllables only in the Padova variety, while in the Reggio Calabria and Napoli varieties intensity seemed to be consistently higher on the first syllable of the word. The data for F0 were found to be more inconsistent and did not reveal any particular pattern, while the data for F1 and F2 appeared to show a certain degree of centralization in the unstressed vowels, especially for the vowel /a/, for which F1 was found to decrease considerably in unstressed position.

In a more recent study (Eriksson *et al.* 2016), the authors analyzed duration, F0 level,[106] F0 variation[107] and spectral emphasis[108] in stressed and unstressed vowels, including secondary stressed vowels (whose results will be discussed in sub-chapter (12.2)), pronounced by 17 native Italian speakers, mostly speaking a variety of Tuscan Italian. The items were pronounced in three conditions related to different speaking styles, namely: spontaneous condition, phrase list condition and word list condition. In the spontaneous condition, speakers participated in a semi-structured interview, from which various target words were extracted. In the phrase list condition and in the word list condition, the same target words were then read by the participants embedded in their original sentence or in isolation, respectively. Among the analyzed parameters, duration was found to be the major correlate, with primary stressed vowels considerably longer than all other vowels. Duration was also found to be higher in word list reading than in the other conditions. With respect to F0 level, the authors found that it was significantly lower in primary stressed vowels than in all other vowels. The authors interpret this as an effect of the intonation pattern typical of a declarative sentence, in which words carrying the last accent might be associated with the lowest F0. F0 level was found to be higher in phrase list reading in comparison to the other conditions. With respect to F0 variation, it was not found to correlate with primary stress and, similarly to F0 level, it was found to be higher in phrase list reading. With respect to spectral emphasis, as for duration, it was found to be a reliable correlate of primary stress, with stressed vowels having higher spectral emphasis. The authors also found a small but significant correlation between spectral emphasis and duration, which they explain as due to the fact that perhaps producing more vocal effort (i.e. higher spectral emphasis) might require more time. Spectral emphasis was also found to be higher in word and phrase list reading. Overall, the authors conclude that, in terms of explained variance, duration can be considered the strongest correlate, followed by spectral emphasis and finally by F0 level, which however might be related to sentence accent more than to word stress.

Sulpizio and McQueen (2012) conducted a psycholinguistic study aimed at analyzing how Italian speakers use acoustic cues related to stress to identify spoken words. As part of the study, one female native Italian speaker read 32 pairs of words, each inserted into the carrier sentence *Clicca sulla parola X* ‘click on the word X’, where X represents the target word. All pairs of words were segmentally identical in the first two syllables and could either have stress on the

[106] Calculated as the median of f0 in the vowel.
[107] Calculated as the standard deviation of f0.
[108] Calculated as $SPL_{full} - SPL_0$ and measured in dB, where SPL_{full} is the sound pressure level of the whole spectrum, while SPL_0 is the sound pressure level of the low-pass filtered segment using a cutoff frequency of $1.5 * f0_{mean}$. This parameter can thus be described as a measure of spectral tilt.

antepenultimate or penultimate syllable, such as *cánapa vs canále*. The authors measured duration, pitch (Hz), amplitude (Pa) and spectral tilt[109] in the first two vowels of each word and they found that in words with antepenultimate stress all four parameters were significantly higher on the stressed antepenult than in the unstressed penult. However, in words with penultimate stress, only duration was significantly higher on the stressed penult in comparison to the unstressed antepenult, while both pitch and amplitude were lower on the penult in comparison to the antepenult and spectral tilt was the same between the penult and the antepenult. These results, although coming from only one speaker, suggest that, with respect to the correlates of stress there might also be a certain degree of variation related to the position of the stressed syllable. With respect to the specific objective of their study, a series of eye-tracking experiments with native Italian speakers was conducted, using the recording of the target words reported above. The results indicated that the participants used the acoustic cues related to stress to recognize words, but only in the case of words with antepenultimate stress, while the words with penultimate stress were recognized by default, which, as the authors note, is in line with the fact that penultimate stress represents the most common pattern in the Italian lexicon. The results also indicated that the manipulation of the acoustic cues in words with antepenultimate stress affected their recognition, while the same did not happen for words with penultimate stress.

Among the studies that analyzed more specifically only duration in Italian, Faretani & Kori (1985) analyzed vowel duration in stressed and unstressed condition, also testing the possible influence of syllable structure (CV *vs* CVC) and number of syllables in the word (2 *vs* 3 syllables). The participants were 3 speakers, one from Tuscany (Central Italy, speaker 1) and two from Lombardy (Northern Italy, speakers 2 and 3), who were recorded reading real words (plus some nonce words) with the vowel /a/. Of the three analyzed variables, stress was found to have the strongest effect on duration in all three speakers, with stressed syllables significantly longer than unstressed syllables. With respect to syllable structure and number of syllables, considerable individual variation was found. With respect to speaker 1, there was a strong effect of number of syllables, with vowels in 3-syllable words having shorter duration than vowels in 2-syllable words, while the effect of syllable structure was weak, with CV syllables being significantly longer than CVC only in half of cases. For speaker 3, the reverse was found, the effect of syllable structure was stronger than that of number of syllables, the latter of which was significant only for stressed CV syllables. For speaker 2, neither syllable structure nor number of syllables showed a strong effect.

A comprehensive study on vowel duration in Italian (Marotta 1985) found an effect of the number of syllables on vowel duration only in words with antepenultimate stress, with 3-syllable

[109] Calculated as the energy ratio between a high and a low frequency band.

words having a shorter stressed syllable than 2-syllable words, but not in words with penultimate or final stress. She also found that stressed vowels in penultimate position are considerably longer than stressed vowels in antepenultimate and final position and that among post-tonic unstressed syllables, syllables adjacent to the stressed syllable tend to be shorter than syllables more distant from the stressed syllable.

Hajek *et al.* (2007) investigated vowel duration in stressed and unstressed syllables, also including the variables of syllable structure (CV *vs* CVC) and stress position (antepenultimate vs penultimate in CV syllables). Their study was conducted on 6 speakers from Central and Southern Italy. The results indicated that stressed CVC syllables were significantly shorter than stressed CV syllables (*páppa vs pápa*) and that antepenultimate CV syllables were significantly shorter than penultimate CV syllables (*pápero vs papáto*). However, the authors did not find any significant difference in duration between the penult and the final (*pápa vs papá*), contrary to the usual assumption in the phonological literature, according to which a final CV syllable is shorter than a non-final one in Italian. A second study was conducted by the same authors (Hajek and Stevens 2008) aimed at analyzing the specific differences between Central and Northern speakers. The same items and methodology of the previous study were used, confirming the results of the previous study and also showing that southern speakers tended to produce shorter vowels in CVC syllables than Northern speakers and that they also tended to produce shorter vowels in antepenultimate position than Northern speakers.

The results of the above mentioned production experiments are also confirmed for the most part by perception experiments, in which participants listen to words which are artificially synthesized or naturally recorded and then manipulated by varying to different degrees one or more of the main acoustic correlates of stress. For instance, in an experiment by Bertinetto (1980), duration, intensity and F0 were manipulated in the string [papa] which, if stressed on the penult, means ‘pope’ while, if stressed on the final, means ‘dad’. The results confirmed that variation in duration played the most important role in stress perception, followed by variation in intensity and finally in F0. In an experiment by Alfano (2006) duration and F0 were artificially manipulated in both real words and nonce words with stress on different positions. The result indicated that the manipulation in duration but not in F0 had a significant effect on stress perception. However, the simultaneous manipulation of both duration and F0 was found to have an even stronger effect than duration alone. Caccia *et al.* (2019) conducted a perception study analyzing the effect of variation in duration, intensity and F0 in reiterated speech in both adults and children. Contrary to the evidence found in most studies, the results indicated that F0 was the strongest cue to stress perception. The authors conclude that this result might be due specifically to the use of reiterated speech, which might perhaps eliminate the influence of the top-down effects found in the real lexicon.

12.2 The acoustic correlates of secondary stress in Italian

To my knowledge, the only comprehensive study on the acoustic correlates of secondary stress in Italian is the one performed by Eriksson *et al*. (2016), already mentioned in sub-chapter (12.1) above, in which the authors also measured the acoustic correlates of primary stress.

In this study, 17 native Italian speakers, mostly speaking a variety of Tuscan Italian, had to read a variety of words in different contexts (the reader is referred to the sub-chapter (12.1) for the details of this study). According to the authors, some of the target words also contained a secondary stress. However, the specific type of analyzed words which are supposed to have a secondary stress is not reported in the study, although the authors specify that the transcription and the different stress levels were based on a pronunciation dictionary.[110] For this reason, it is possible that the words transcribed as having a secondary stress were compounds, in which, in Italian, the constituent bearing primary stress is usually on the right, and the constituent on the left could theoretically be thought as bearing a secondary stress on the syllable that originally had a primary stress, as in *pòrta#bagágli***,** 'car's trunk' from *pórta* 'carry.imperative' and *bagágli* 'luggage'. As was the case for primary stress, also for secondary stress the authors measured duration, F0 level,[111] F0 variation[112] and spectral emphasis[113] as possible acoustic correlates. The results suggest that only spectral emphasis could be considered a reliable correlate of secondary stress in Italian. More specifically, secondary stressed vowels were found to have significantly higher spectral emphasis than unstressed vowels and significantly less spectral emphasis than primary stressed vowels. A minimal effect of F0 variation was found, with secondary stressed vowels showing lower levels of variation in F0. With respect to duration, a significant difference was found between unstressed, secondary stressed and primary stressed vowels, however secondary stressed vowels were found to be shorter than unstressed vowels, so that duration cannot be considered a reliable correlate of secondary stress, in spite of it being the strongest correlate of primary stress.

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110 The pronunciation dictionary cited in the study is the *Dizionario italiano multimediale e multilingue d'Ortografia e di Pronunzia [Online]*. Available at http://www.dizionario.rai.it/.
111 Calculated as the median of F0 in the vowel.
112 Calculated as the standard deviation of F0.
113 Calculated as $SPL_{full} - SPL_0$ and measured in dB, where SPL_{full} is the sound pressure level of the whole spectrum, while SPL_0 is the sound pressure level of the low-pass filtered segment using a cutoff frequency of 1.5 * $F0_{mean}$. This parameter can thus be described as a measure of spectral tilt.

More recently, Brugnoli (2019) analyzed duration, intensity, F0, F2 and spectral tilt[114] as possible acoustic correlates of secondary stress in two words, namely *càmaleónte* 'chameleon' and *magàzziniére* 'warehouse worker'. Of the two target words, *càmaleónte* is supposed to have a secondary stress on the first syllable, because of the left-to-right directionality of secondary stress in Italian, while *magàzziniére* is supposed to have a secondary stress on the second syllable, because of the influence of syllable weight (see sub-chapter 3.4). Therefore, in the case of *càmaleónte*, the analyzed parameters were expected to be higher on the first syllable in comparison to the second unstressed syllable, while in the case of *magàzziniére*, they were expected to be higher on the second syllable in comparison with the first unstressed syllable. The results suggested that among the investigated parameters only intensity could be considered as a reliable acoustic correlate of secondary stress, since it was found to be significantly higher on the first syllable of *càmaleónte* and on the second syllable of *magàzziniére*, in comparison to the respective unstressed syllables.

12.3 Conclusions

Overall, the majority of studies on the acoustic correlates of primary stress confirm duration as by far the most reliable correlate, with primary stressed vowels as significantly longer than unstressed ones. The studies conducted so far also highlight how vowel duration might interact in a complex way with other variables, such as stress position, syllable structure and compression effects related to word length. The role of duration as major correlate of primary stress is also evidenced in perception experiments.

With respect to the other investigated parameters, the role of intensity remains less clear, since intensity seems to surface as a correlate of stress only in a minority of cases, and when it does so it is usually found to play a less important role than duration. F0 does not usually turn out to be a reliable correlate of stress in Italian, rather it seems to be mostly related to intonation, although some level of interaction with word stress might still be present. Formant frequencies remain mostly understudied as correlates of stress in Italian, although especially F1 (on the basis of Romito 1994's descriptive data) might be a likely candidate as possible correlate of stress. Spectral tilt, although not heavily studied, seems also to play a role in primary stress production in Italian.

With respect to secondary stress, the evidence so far, although scarce, seems to suggest that only intensity and spectral tilt (itself a parameter related to intensity) might be considered reliable acoustic correlates of secondary stress in Italian.

[114] Extracted in Praat as the 'the logarithmic power spectral density as a function of frequency, expressed in dB/Hz relative to 2·10-5 Pa.' (Boersma & Weenink 2023).

It should also be noted that all the studies surveyed above presented many external variables, for example in relation to the characteristics of the participants taking part in the studies, especially with respect to diatopic variation, which in the case of Italian can be considered particularly diverse at the prosodic level, or in relation to the type of stimuli used and the intonational context in which the stimuli are inserted. All these aspects should thus be taken into account when planning and comparing studies on stress, since they might be responsible for a large portion of the variability found in the results.

13 The acoustic correlates of stress in German

13.1 The acoustic correlates of primary stress in German

The acoustic correlates of primary stress in German have been the object of study both in production (e.g. Aronov and Schweitzer 2016, Schmid and Moosmüller 2017, among the most recent) and perception experiments (Kohler 2012, Niebuhr and Winkler 2017). This chapter will deal exclusively with production studies, since the experiment presented in chapter (15) is also a production experiment. The production studies conducted so far on stress in German have analyzed the acoustic correlates of stress using different methodologies, with respect to the recording conditions (e.g. word list reading *vs* spontaneous speech), items used (e.g. real words, *vs* nonce words), prosodic context (accented *vs* unaccented) and others. Some studies also analyzed the acoustic correlates of stress in relation to the distinction between tense and lax vowels (e.g. Mooshammer and Geng 2008), which plays a role in German phonology and, as will be shown below, can lead to different results also with respect to the acoustic correlates of stress. Most of the studies discussed here were conducted on the standard variety of German spoken in Germany, while a minority of studies were conducted on Austrian German. For each of the studies under discussion, when not otherwise specified, the study refers to the variety of German spoken in Germany.

In one of the first comprehensive study on German (Dogil and Williams 1999) the authors compared the stressed syllable in *Kónstanz* (name of city) with the unstressed syllable in *Konstánz* 'stability', read by two males and one female, measuring duration, intensity, F0, voice onset time (VOT) and the difference between the first two formants F2-F1. Although their study remained purely descriptive (no statistical analysis was performed) the authors concluded that duration was the strongest acoustic correlate of stress, with stressed vowels systematically shorter than unstressed vowels. However, they also noted that unstressed vowels had a more centralized spectral structure and also that the onset consonants in unstressed syllables had considerably shorter VOT than in stressed syllables. With respect to F0, their results indicated that the stressed syllables carried a pitch accent, highlighting the possibility of an interplay between stress and accent. In a second experiment with 5 female speakers, the authors investigated the same parameters (except VOT) in stressed and unstressed vowels in the word *Liliputáner* and in the corresponding version in reiterated speech, *dadadadáda* in focus and non-focus condition. In both words, for which also a statistical analysis was performed, contrary to the results of the previous experiment, the authors found only duration to be a significant correlate of primary stress, with no difference between focus conditions.

The relevance of formant frequencies in differentiating stressed and unstressed vowels was also investigated by Moosmüller (2007), who ran a production experiment in Austrian German in which she analyzed the duration and formant structures (F1, F2 and F3) by recording 3 male speakers and 3 female speakers in spontaneous interviews and in sentence reading task. The results confirmed that stressed vowels had significantly higher duration and also indicated that, overall, change in F2 was the strongest cue to the stressed/unstressed distinction (while change in F3 was the weakest cue), except in the case of the vowel /a/, for which F1 was the most important formant in distinguishing stress levels.

Schneider and Möbius (2006) analyzed duration, intensity, F0, F1 and F2[115] in nonce words with CV syllables pronounced by 3 children (aged 2 to 6) and their mothers and found duration to be the strongest reliable correlate of stress in both children and adults. F0 was also found to correlate with stress in both adults and children, although the authors acknowledge that it might also be related to the specific intonation patterns used, i.e. child-directed speech. Intensity was found to be more inconsistent, especially in adults. F1 and F2 were both found to depend on stress to some degree in both adults and children, but not in a systematic way.

Mooshammer and Geng (2008) conducted a study aimed at investigating vowel reduction in German and did so by comparing words with tVt sequences with either lax or tense vowels in a stressed and accented condition *vs* an unstressed and unaccented condition. The words were read by 7 native German speakers from different parts of Germany. In order to analyze the effect of the two conditions on vowel reduction, the authors measured duration and formant frequencies and found that tense vowels in the unstressed condition were both shorter and more centralized than in the stressed condition, while lax vowels in the unstressed condition also underwent centralization but were not affected in terms of duration. With respect to centralization, low vowels tended to be more affected than high vowels and variation in F1 was found in general to be stronger than variation in F2. The authors also analyzed tongue movement through electromagnetic midsagittal articulography (EMMA) and found for all vowels in the unstressed condition a higher tendency to undergo coarticulation with the surrounding consonants.

Unlike most studies on the acoustic correlates of word stress in German, Aronov and Schweitzer (2016) analyzed stressed and unstressed vowels in words taken from a large corpus of spontaneous speech, instead of from a controlled condition. The authors measured duration at the level of the syllable instead of at the vowel, pitch and two measures of spectral tilt, one calculated as the slope of a linear regression line of the spectrum (between 0 and 5000Hz) and the other by calculating the difference between the mean intensity of two frequency bands B1 (0-0.5 kHz) and

[115] The authors also measured a series of 'voice quality' parameters that are not discussed here.

B2 (0.5-1.0 kHz). With respect to syllable duration, the authors found that stressed syllables were on average longer than unstressed syllables, confirming the role of duration as an important correlate of stress in German also at the level of the syllable. On the contrary, pitch did not differ significantly between stressed and unstressed vowels. With respect to the first measure of spectral tilt (slope of regression line), the results indicated a significantly steeper slope for stressed vowels, which, as the authors note, is contrary to expectations that in stressed vowels intensity at high frequencies decreases less steeply than in unstressed vowels. With respect to the second measure of spectral tilt (B2-B1 difference), the results indicated a significantly larger difference for unstressed vowels, i.e. a steeper slope, which is in accordance with expectations. With respect to these contrasting results, the authors conclude that the claim that unstressed vowels should have a steeper spectral tilt might hold only for lower frequencies, as was the case of the B2-B1 type of spectral tilt, in which the frequency range analyzed was lower than that of the slope-of-regression-line type.

One recent comprehensive study on stress in German was conducted by El Zarka *et al.* (2017) in Austrian German. The authors extracted instances of the vowel /a/ from words in a corpus of spontaneous speech pronounced by male and female speakers within an age range of 20-60 years. The analyzed parameters were duration, F1, F2, F3 and four different measures of spectral tilt, i.e. H1-H2, H1-A1, H1-A2 and H1-A3.[116] Many different variables were also taken into account, such as focus condition or syllable structure, plus other variables related to the intonational structure of the sentences that contained the extracted vowels that are not explicitly discussed here[117]. One aspect that has to be mentioned is that the authors distinguish in their study between 'metrical stress', i.e. the classical definition of word stress in the phonological sense and 'perceived prominence', i.e. a variable which was obtained by having four annotators judge which syllables were more prominent. The latter variable does not necessarily match with the former and concerns a type of prominence where stress and accent might also be conflated. With respect to duration, the results indicated that duration is a statistically significant correlate of stress and that the effect is stronger for 'perceived prominence' than 'metrical stress'. Duration was also found to be longer in open *vs* closed syllables. With respect to formant frequencies, F1 was found to be higher in stressed vowels, while F2 and F3 were found to be moderately lower in stressed vowels, which is in line with a more peripheral back /a/ vowel in stressed position. The same effect was also found with respect to syllable structure, i.e. /a/ vowels in open syllable had higher F1 and lower F2 and F3, indicating more peripheral back vowels than in the closed syllable counterpart, which had a more central quality instead, in line with the opposition of a tense /a/ in open syllables and a lax /a/ in

[116] H1 and H2 represent the first and second harmonics respectively, A1, A2 and A3 represent the amplitude peaks in the vicinity of the first, second and third formant respectively.
[117] For the complete list of the analyzed external variables *cfr*. Zerka *et al.* 2017:12.

closed syllables. However, only the values for F1 were found to be statistically significant. With respect to spectral tilt measures, the results indicated that H1-A2 and H1-A3 are the most reliable measures, but only of 'perceived prominence' and not of 'metrical stress'. Overall, the authors conclude that duration, F1 and in part spectral tilt seem to be better correlated with 'perceived prominence' than with 'metrical stress'.

Another more recent study comparing the acoustic correlates of stress in the variety of German spoken in Germany (GG) and the variety spoken in Austria (AG) (Schmid and Moosmüller 2017) had speakers of both varieties read four disyllabic words with stress on the first syllable (CV́CV). The extracted acoustic parameters were duration, F0, intensity and formants F1, F2 and F3. The results indicated that, in the case of F0, significant differences between stressed and unstressed vowels were found in both varieties only for female speakers, however with opposite results between the two varieties, i.e. in GG F0 was higher in the stressed vowels, while in AG it was higher in the unstressed vowels. With respect to duration, stressed vowels were found to be significantly longer in both varieties, but the effect was stronger in AG. Intensity, as in the case of duration, was also found to be a significant parameter in both varieties, with stressed vowels having higher intensity than unstressed vowels. With respect to formants, in both varieties formant frequencies were found to distinguish stressed and unstressed vowels, but vowels were found to reduce more in unstressed position in GG than in AG, in the latter of which furthermore the difference was found to be significant only for females.

13.2 The acoustic correlates of secondary stress in German

The acoustic correlates of secondary stress in German have not been the object of extensive research. As is the case in Italian, the lack of research in this area might also be due to the uncertainties surrounding the definition and position of secondary stress in German. In spite of these issues, some studies have been produced which have tried to isolate some possible acoustic correlates of secondary stress in German, although they often differ in the analyzed types of words which are supposed to bear a secondary stress.

One first relevant study is the one made by Jessen (1993). This study was not specifically aimed at investigating the acoustic correlates of secondary stress in German, but rather at investigating the acoustic correlates of the distinction between tense and lax vowels, specifically with respect to duration, F1, F2 and F3. However, because of the structure of the items used, it can also provide some insights with respect to the acoustic manifestation of secondary stress. More specifically, in order to analyze the acoustic correlates of the distinction between tense and lax vowels, the author ran two experiments. In the first experiment the author compared tense and lax vowels in stressed position (e.g. *Ni.trí.lisch*) with tense and lax vowels one syllable before primary stress position (e.g. *ni.tri.líst*).[118] In the second experiment the author compared tense and lax vowels in stressed position (e.g. *Bé.ten*) with the same vowels two syllables before primary stress (e.g. *Be.te.réi*). The results of the first experiment indicated that, in stressed position, tense and lax differed in both quality (i.e. formant structure, with tense vowels significantly more peripheral than lax vowels) and duration (with tense vowels significantly longer than lax vowels), however tense and lax vowels one syllable before primary stress differed only in quality (i.e. tense vowels were more peripheral) but not in duration, suggesting perhaps that tense vowels shorten in unstressed position but lax vowels keep the same duration as in stressed position, corroborating the results which were also found by Mooshammer and Geng (2008). The results of the second experiment confirmed that in stressed position tense and lax differed both in quality and duration, however it was found that tense and lax vowels two syllables before primary stress also differed both in quality and duration. As the author notes, these results might be interpreted as due to the presence of a secondary stress two syllables before primary stress, which prevents tense vowels from shortening as was instead the case in vowels one syllable before primary stress.[119] The results would thus suggest duration as a correlate of secondary stress, at least for tense vowels and in the specific type of words tested in these experiments (σσσ́). However, because of the specific aim of the experiment, i.e. to analyze the acoustic correlates of the difference between tense and lax vowels, no statistical analysis was performed comparing the investigated acoustic parameters in stressed and unstressed (either one or two syllables before primary stress) vowels, so these conclusions should be taken with caution.

Kleber and Kilpphahn (2006) conducted a study specifically aimed at detecting the acoustic correlates of secondary stress in German. Different types of words containing both tense and lax vowels, inserted into the carrier sentence *Ich habe X gesagt*, were read by 6 female speakers (however, the final results were based only on 4) and from these words, three types of target syllables were extracted and compared: stressed syllables, i.e. the first syllable in σ́(σ) words, e.g. *Mé.dien*, syllables separated from primary stress by one syllable, i.e. the first syllable in σσσ́(σ) words, e.g. *Me.di.zí.ner*, a context where the syllables were expected to bear secondary stress, and syllables immediately preceding the stressed syllable, i.e. the first syllable in σσ́(σ) words, e.g. *me.diál*, which represented unstressed syllables. The analyzed parameters were duration, F0 (at

[118] As the author notes, some of the used items are not real words, but they are still words created by combining existing stems and existing suffixes.
[119] The vowel two syllables before primary stress, which on the basis of these results is supposed to bear a secondary stress, was always in a word-initial syllable, which is in line with the assignment of a secondary stress in accordance with a left-to-right directionality (see chapter 4), e.g. *Bèteréi* (tense vowel) and *Bètteréi* (lax vowel).

different points in the vowel), F1, F2 and intensity (at midpoint). With respect to duration, the results indicated that tense vowels were always significantly shorter in unstressed position in comparison to when they bore a primary stress, but for lax vowels the difference was significant only in few cases, suggesting results similar to those found by Jessen (1993) and Mooshammer and Geng (2008). Overall, the difference in duration with respect to all three levels of stress (i.e. including secondary stress) was not significant and was also rather inconsistent (i.e. unstressed vowels sometimes longer than vowels with secondary stress). With respect to intensity, the values were found to be inconsistent and mostly not statistically significant for all three levels of stress. With respect to F0, it was found to be generally significantly higher in the primary stressed syllables in comparison to the other two types of syllables, but no difference with respect to secondary stress was found. With respect to formants F1 and F2, which were measured on vowels of different qualities, the values were found to be consistent and differentiating between all three levels of stress only in some cases and for some vowels, indicating a high level of variability both among vowels and speakers. Overall, the authors conclude that no reliable correlates of secondary stress could be found.

In one study already mentioned above (Mossmüller 2007), the author analyzed duration and formant structures (F1, F2 and F3) of tense and lax vowels in Austrian German, by recoding 3 male speakers and 3 female speakers in spontaneous interviews and in a sentence reading task. Among her analyses, the author also measured the first three formants in secondary stressed vowels in comparison to primary stressed vowels and unstressed vowels. In her experiment, the items which were supposed to bear a secondary stress were morphologically complex words, such as compounds in which a secondary stress is deemed to be present on the syllable that originally bore a primary stress, as in *Nébenfàch* 'secondary subject' from *nében* 'next to' + *Fách* 'subject'. The results indicated a very high level of variability among the 6 speakers, suggesting no clear uniform way to signal secondary stress through formants. Among the different vowels investigated, the clearest results emerged for the tense vowel /a/[120] with respect to F1, which, in secondary stressed vowels, was found to systematically have a middle value between primary stressed vowels and unstressed vowels for all 6 speakers.

In a more recent study, already mentioned in (13.1), El Zarka *et al.* (2017) also analyzed secondary stress in Austrian German. As in the case of Moosmüller (2007), a secondary stress was deemed to be present in compound forms, in which primary stress is usually on the leftmost constituent while the constituent on the right is supposed to have a secondary stress on the syllable that originally bore a primary stress, such as in the compound *Vídeo-Gègen#sprech#anlage* 'video

[120] In Moosmüller's study, it is transcribed as /ɑ/.

interphone', in which the first constituent, *Vídeo*, bears the primary stress of the whole compound, while the second constituent *Gègen#sprech#anlage* is supposed to bear a secondary stress on the first word, in this case *gégen* 'against', which bears a primary stress on the first syllable when not used in a compound. However, the authors also note that this abstract categorization of secondary stress, which they label 'metrical stress', does not always correspond to what is actually perceived, so they also included in their analysis the variable 'perceived prominence', by having four annotators mark each of the target syllables as either 'very prominent', 'prominent' o 'none', in order to also have a second assessment with respect to secondary stress presence and position. However, it has to be noted that this type of perceived prominence might also be occasionally associated with changes in pitch due to the intonational contour (accent) rather than exclusively to word stress. The variable 'perceived prominence' is thus analyzed alongside the variable 'metrical stress', which marks the levels of stress in compounds in the way described above. The authors measured duration, F1, F2, F3 and four different measures of spectral tilt, i.e. H1-H2, H1-A1, H1-A2 and H1-A3.[121] Concerning duration, the difference between the three levels of stress for 'metrical stress' was found to be only marginally significant, while it was significant in the case of 'perceived prominence', with syllables perceived as having the highest prominence being longer than syllables perceived as less prominent, which were in turn longer than syllables with no perceived prominence. This might perhaps suggest that secondary stress does not necessarily arise in compound forms only, i.e. it is not exclusively related to stress preservation, as discussed chapter (2.3 and 4.4). With respect to formant frequencies F1, F2 and F3, the results suggested that only F1 distinguished in a statistically significant way the three levels in both 'metrical stress' and 'perceived prominence'. With respect to spectral tilt measures, none of the analyzed measures proved to be reliable correlates of secondary stress.

Brugnoli (2019) analyzed secondary stress in two words, namely *Kàpazitä́t* and *Adàptatíon,* read by 7 female speakers. The word *Kàpazitä́t* was supposed to bear a secondary stress on the first syllable because of the left-to-right directionality of secondary stress, while *Adàptatíon* was supposed to bear a secondary stress on the second syllable with a consonant in the coda because of the influence of syllable weight (see sub-chapter 4.4). The analyzed parameters were duration, intensity, F0, F2 and spectral tilt.[122] With respect to the results, both duration and F2 and were found to be higher in the second syllable, while spectral tilt was found to always have higher negative values on the first syllable but all the differences with the unstressed vowels were not

[121] H1 and H2 represent the first and second harmonics respectively, A1, A2 and A3 represent the amplitude peaks in the vicinity of the first, second and third formant respectively.
[122] Extracted in Praat as the 'the logarithmic power spectral density as a function of frequency, expressed in dB/Hz relative to 2·10-5 Pa.' (Boersma & Weenink 2023).

statistically significant. Intensity and F0 were found to be in line with the expectations, i.e. higher on the first syllable of *Kàpazitắt* and on the second syllable of *Adàptatíon*, but the difference with the respective unstressed syllables was not statistically significant. Overall, no reliable acoustic parameters of secondary stress could be found.

13.3 Conclusions

With respect to primary stress, all studies point to duration as the strongest acoustic correlate in German, with stressed vowels significantly longer than unstressed vowels. All the studies that included as a variable the tense/lax vowel distinction also found that stress significantly affects duration of tense vowels, which are longer in stressed position, but not of lax vowels, which have about the same duration in stressed and unstressed position. One study (Aronov and Schweitzer 2016) also suggests duration of the entire syllable as a reliable correlate of stress.

Formant frequencies (mostly F1 and F2) seem to be the second most reliable correlate of primary stress after duration, although the importance that each formant plays in signaling stress might vary considerably depending on the type of vowel investigated.

With respect to intensity, it does not seem to be a reliable correlate in the majority of studies, although it was found to be significantly higher in stressed syllables in both German and Austrian German by Schmid and Moosmüller (2017).

Also F0 does not seem to be a reliable correlate, perhaps interacting with intonation and accent in a way that makes it difficult to assess its importance with respect to stress. The variability in the studies with respect to the condition in which the target words are tested, i.e. accented or unaccented, makes it also difficult to compare the results concerning F0.

Spectral tilt has not been extensively investigated and has yielded contrasting results, also due to the variety of ways in which it can be measured, perhaps indicating that specific measures in specific frequency bands might yield more robust results when analyzing stress distinctions.

With respect to secondary stress, perhaps also due to the scarcity of studies that have been conducted so far, no reliable correlates can be clearly singled out. The most likely candidate seems to be represented by formant frequencies, especially F1, which, more specifically, was found to somewhat correlate with secondary stress only in two studies on Austrian German, whose results can thus not be directly generalized to the German variety spoken in Germany. Duration might also be a possible correlate of secondary stress, as perhaps in particular the results of Jessen (1993) seem to suggest for σσσ́ words.

The difficulties in detecting clear correlates of secondary stress are also strongly related to the uncertainties concerning the type of words that are supposed to bear a secondary stress and in the difficulties in establishing the exact position of secondary stress within the word. More research using a more diversified variety of types of words is thus needed in order to overcome this issue.

14 Experiment on the acoustic correlates of stress in Italian

14.1 Research questions

The following experiment is aimed at detecting the acoustic correlates of primary and secondary stress in Italian. As shown in chapter (12), with respect to primary stress, duration has been found to be a robust correlate in most studies, however the role of other acoustic parameters remains still unclear.

With respect to secondary stress, the very few studies conducted so far suggest intensity and spectral tilt as possible correlates, however more research is needed to corroborate these results and to understand the role of other possible acoustic correlates.

The following experiment is thus aimed at either confirming or disproving previous results with respect to the acoustic correlates of primary and secondary stress and possibly to single out new correlates.

Furthermore, some external variables which might play a role in the way stress is realized are also taken into consideration. More specifically, some studies (e.g. Romito 1994, Hajek *et al*. 2007, Sulpizio and McQueen 2012) seem to suggest that the acoustic realization of stress might differ depending on its position within the word, for instance the acoustic correlates of a stressed vowel in penultimate position might differ from those of the same vowel stressed in antepenultimate position. This is also suggested by the well known fact in the phonological literature for Italian that, for example, a stressed vowel in penultimate position has a significantly longer duration than the same vowel in antepenultimate or final position (see sub-chapter 3.2). For this reason, with respect to primary stress, besides trying to answer the more general questions of which are its main acoustic correlates, the issue of whether the acoustic correlates of stress vary depending on the position of the stressed syllable within in the word will also be investigated.

With respect to secondary stress, one issue which has not been investigated before is whether secondary stress might be realized as more prominently (or in a different way) depending on the length of the inter-stress interval, i.e. depending on the distance in terms of number of syllables before primary and secondary stress. Studies on primary stress (e.g. Marotta 1985) found contrasting results with respect to whether a stressed syllable changes significantly in duration depending on the length of the word in terms of syllables, highlighting the need for further research on this topic. Concerning more specifically secondary stress, as discussed in chapter (3), Bertinetto and Loporcaro (2005) suggest that in Italian the retention of lax vowels in unstressed position in compounds might be interpreted as due to the presence of a secondary stress, e.g. *[ˌpɔrtaomˈbrɛlli]* instead of *[portaom'brɛlli]*, and they note that the likelihood to retain the lax vowel increases with the inter-stress interval, supporting the idea that perhaps secondary stress is realized more prominently as a function of the length of the inter-stress interval between secondary and primary stress. For this reason, as was the case for primary stress, besides analyzing at the general level which are the acoustic correlates of secondary stress, the issue of whether secondary stress is manifested more prominently by increasing the inter-stress interval will also be investigated.

The research questions that will be addressed in this experiment are thus summarized in (53).

(53) Research questions on the acoustic correlates of primary and secondary stress in Italian.

a. What are the acoustic correlates of primary stress?

b. Do the acoustic correlates of primary stress change with respect to the position of the stressed syllable within the word?

d. What are the acoustic correlates of secondary stress?

e. Are the acoustic correlates of secondary stress manifested more prominently or differently depending on the length on the interval in terms of syllables between primary and secondary stress?

14.2 Methodology

14.2.1 Participants

30 native Italian speakers were recruited to participate in a production experiment. These participants were the same that took part in the nonce word experiment in chapter (6). The experiment on the acoustic correlates of stress took place immediately after the nonce word experiment. The data concerning the participants presented in chapter 6 are thus reported again here.

The participants are 17 females and 13 males, the age range is 21-64 years old with a mean age of 36.6. With respect to age, the participants can be roughly divided into two groups, one comprising the younger participants: age range 21-37 (14 females and 5 males), with a mean age of 24.6 years old, and the other comprising the older participants: age range 43-64 years old (3 females and 8 males), with a mean age of 56.4. The participants come mostly from Northern Italy, except 2 who come from Central and Southern Italy. More specifically, among the participants from Northern Italy, 21 come from Veneto, 5 from Lombardia and 2 from Trentino-Alto Adige. 1

participant comes from Lazio in central Italy and 1 from Puglia in Southern Italy. The places of origin by region are summarized in figure (7).

All participants were also asked to indicate whether they were bilingual (i.e. whether they spoke a second language natively, besides Italian) and whether they actively spoke a dialect. 1 participant stated to be bilingual Italian-Arabic and 6 participants stated that they spoke a dialect. The relevant information about the participants is summarized in appendix (1).

Most of the younger participants were recruited among students at the University of Verona, while the remaining participants were recruited among acquaintances of the experimenter or through other means.

Figure (7). Map of the places of origin of the Italian participants by region.

14.2.2 Items

In order to analyze the acoustic correlates of primary stress, three words were chosen, i.e. *cánapa* 'hemp', *patáta* 'potato' and *maragiá*[123] 'maharaja'. All target words contain the vowel /a/ in all syllables in order to reduce the variability related to vowel quality for the acoustic parameters when comparing stressed and unstressed vowels, especially with respect to duration and formant frequencies, both of which vary strongly depending on the type of vowel.

The three target words consist all of three syllables and bear primary stress on the antepenultimate, penultimate and final syllable respectively. The variability in the position of primary stress among the target words was added in order to investigate the research question of whether the acoustic correlates of stress change with respect to stress position within the word.

In order to analyze the acoustic correlates of secondary stress, two words were chosen, i.e. *càtaláno* 'Catalan' and *càtamaráno* 'catamaran'. As was the case for primary stress, both words contain the vowel /a/ in all syllables in order to reduce the variability related to vowel quality when comparing secondary stressed and unstressed syllables.

Both *càtaláno* and *càtamaráno* bear primary stress on the penultimate syllable and are deemed to bear a secondary stress on the first syllable, based on the assumption that Italian has directionality of secondary stress from left-to-right (see chapter 3.4), i.e. secondary stress is placed on the first syllable in a word like *(càta)maráno,* building a disyllabic trochaic foot on the left and leaving a syllable unparsed on the right before primary stress. In the case of (*càta)láno,* assuming the formation of a disyllabic trochaic foot, secondary stress can only fall on the first syllable, since it would otherwise incur in a stress clash with the primary stressed syllable, which is usually thought not to be possible in the stress system of Italian.

The two words with secondary stress differ in the inter-stress interval, i.e. in the number of syllables that separate the primary stressed syllable and the secondary stressed syllable, namely *cà.ta.lá.no* has one unstressed syllable between primary and secondary stress, while *cà.ta.ma.rá.no* has two unstressed syllables between primary and secondary stress. The variable of the inter-stress interval was added in order to investigate the research question of whether the degree of prominence on syllables bearing secondary stress correlates with the number of unstressed syllables between secondary and primary stress.

All items used in the experiment are reported in table (35).

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[123] In Italian orthography, stress on the final syllable on the vowel <a> is usually marked with a grave accent, so that the word for 'maharaja' would be written <maragià>, while no stress diacritics is used to mark stress on syllables other than the final in Italian. The form <maragià> was thus the one used in the list that the participants in the experiment had to read aloud (see section 14.2.4). In this chapter, the form <maragiá>, with an acute accent, will be used, in accordance with the convention used throughout this thesis of using an acute accent to mark primary stress.

Table (35). Items used to analyze the acoustic correlates of primary and secondary stress in Italian.

Level of stress investigated	**Items**	**Notes**
Primary stress	*cánapa*, *patáta*, *maragiá*	The items differ in the position of primary stress
Secondary stress	*càtaláno*, *càtamaráno*	The items differ in the length of the inter-stress interval

14.2.3 Acoustic parameters

Six acoustic parameters were analyzed in the target vowels as possible acoustic correlates of either primary or secondary stress: vowel duration (ms), average intensity (db), average F0 (Hz), formant frequencies F1 and F2 calculated at midpoint (Hz), and spectral tilt (db/Hz), which was calculated through the 'Report spectral trend' function in *Praat*, which computes a linear regression between intensity and frequency in a frequency spectrum comprised between 1 and 5000 Hz and returns as output the value of the slope expressed in db/Hz (the returned slope has a negative value, since the relationship between intensity and frequency is inversely proportional).

With respect to the comparison between (primary or secondary) stressed vowels and unstressed vowels the expectations are different for the various parameters. Duration and intensity are expected to be higher on the stressed vowel. F0 is expected to be higher on the stressed vowel, however also the contrary could be expected, on the basis of Eriksson *et al.* (2016)'s results in which F0 was found to be lower on the stressed vowels in Italian (see chapter 12). F1 is expected to be higher in the stressed vowel, indicating a lower/more peripheral [a]. F2 is expected to be lower in the stressed vowel, indicating a more back/more peripheral [a]. The expectations for F2 are based on Romito's (1999) formant chart for stressed and unstressed vowels containing also the vowel [a], in which stressed [a] has a slightly lower F2 values than unstressed [a] in the Padova variety of Italian, which is a Northern variety of Italian, similar to the one spoken by most of the participants in the present experiment. Spectral tilt, which has always negative values (e.g. -0.00678) is expected to have higher values (i.e. less negative, closer to 0) on the stressed vowel, indicating a less steep tilt, i.e. indicating that, in stressed vowels, intensity decreases less at higher frequencies than in unstressed vowels, for which a lower value (more negative) is expected, indicating a steeper tilt. One example with respect to the expectations for spectral tilt would be to have a stressed value with a value of -0.00724 and an unstressed vowel with a value of -0.00765.

14.2.4 Procedure

The 5 target words (3 for primary stress and 2 for secondary stress) were inserted in a list together with filler words. Each word of the list was inserted into the carrier sentence *Ha detto di nuovo X* ‘He/she said X again’, where X represents a target word or a filler. The carrier sentence was used in order to make sure that the target words were in accented position and also to have all target words inserted in the same prosodic context. The items in the list were pseudo-randomized.

Each participant read aloud the list three times in a quiet room and was recorded using an Olympus LS-10 linear pcm recorder. Recordings were sampled at 44.1 kHz/16 bit.

All recordings were manually transcribed and automatically segmented using the *WebMaus* software (Schiel 1999). The segmentation obtained through *WebMaus* was then manually corrected, following the criteria discussed in Turk *et al.* (2006). Overall the segmentation of the 5 target words was not problematic and the vowel boundaries were clearly detectable.

A Praat script was used to extract the acoustic parameters mentioned in section (14.2.3) from each vowel of the target words. All instances of words that were mispronounced or pronounced with hesitation were deleted from the analysis. In the case of the items with secondary stress, most of the items were deemed to have a secondary stress on the initial syllable, although in many cases the prominence of this type of secondary stress is very weak and not easily detectable.

The data were analyzed through mixed-effects regression analysis using the *lmer* package in *R* (R Core Team 2021) Two different sets of analyses were performed, one on the three items proposed for the analysis of primary stress and one on the items proposed for the analysis of secondary stress. For each investigated acoustic parameter a model was built including the relevant acoustic parameter as dependent variable.

In the case of primary stress, the relevant acoustic parameter was included as dependent variable (e.g. *Duration*) and the following variables were included as predictors: *Stress*, referring to stressed or unstressed vowels, *Stress_position*, referring to the three tested words, which had stress either on the antepenult (*cánapa*), penult (*patáta*) or final (*maragiá*), *Sex*, *Age* and *Region* of the participants. The variable *ID*, referring to the single participants, was added as random effect. In order to analyze the possible effect of *Stress_position* on *Stress* an interaction was created between these two variables, so that the maximum model, using *Duration* as dependent variable, looks like this:

(54) Duration ~ Stress*Stress_position + Sex + Age + Region + (1|ID)

Model selection was performed using the stepwise variable selection procedure implemented in the *step()* function, which selects the best model based on AIC values. The *step()* function was thus applied to the model in (54), returning as output the best-fitting model. The best fitting model was further analyzed through the *summary()* function.

In order to further investigate the research questions concerning whether the acoustic correlates of primary stress might manifest differently in different positions within the word, pairwise comparison through the *emmeans* package in R was performed between the stressed vowels of *cánapa patáta* and *maragiá* for those parameters in which the interaction between *Stress*Stress_position* was found to improve the model.

In the case of secondary stress, the relevant acoustic parameter was included as dependent variable (e.g. *Duration*) and the following variables were included as predictors: *Sec_stress*, referring to the first or second vowel, i.e. to the secondary stressed vowel or the unstressed vowel immediately following the secondary stressed vowel, respectively. The second added predictor was *Interval*, referring to the two tested words, one with an inter-stress interval of one syllable, i.e. *càtaláno*, and one with an inter-stress interval of two syllable, i.e. *càtamárano.* The other predictors were *Sex*, *Age* and *Region.* The variable *ID*, referring to the single participants, was added as random effect. In order to analyze the possible effect of *Sec_stress* on *Interval* an interaction was created between these two variables, so that the maximum model, using *Duration* as dependent variable, looks like this:

(55) Duration ~ Sec_stress*Interval + Sex + Age + Region + (1|ID)

Model selection was performed using the stepwise variable selection procedure implemented in the *step()* function, which selects the best model based on AIC values. The *step()* function was thus applied to the model in (55), returning as output the best-fitting model. The best fitting model was further analyzed through the *summary()* function.

In order to further investigate the research questions concerning whether secondary stress is manifested more prominently in words with a higher inter-stress interval, pairwise comparison through the *emmeans* package in R was performed between the first secondary stressed vowel of *càtaláno* and the first secondary stressed vowel of *càtamárano* for those parameters in which the interaction between *Sec_stress*Interval* was found to improve the model.

14.3 Results

The following tables show the values of stressed and unstressed syllables for each of the investigated acoustic parameters. In each table, shaded cells of a row indicate that the insertion in the model of the variable *Stress*, which is the main predictor, significantly improved the model for that acoustic parameter ($p < 0.05$). For each acoustic parameter, the highest value of that parameter is highlighted in bold.

The column of each table labeled 'Significant variables' reports all the variables that were found to significantly improve the model for a particular acoustic parameter, i.e. *Stress, Sex*, *Age*, *Region* and, only for primary stress, *Stress_position* and/or its interaction with *Stress*, i.e. *Stress*Stress_position* and, only for secondary stress, *Sec_stress* and/or its interaction with *Interval*, i.e. *Sec_stress*Interval*. The column labeled 'Pairwise comparisons: stressed vowels', reports the results of the comparison between the primary stressed vowels (in the case of *cánapa, patáta* and *maragiá*) or between the secondary stressed vowels (in the case of *càtaláno* and *càtamárano*).

The results concerning primary stress are reported first in tables (36-43), followed by the results concerning secondary stress reported in tables (44-48).

With respect to primary stress, table (36) reports the results pooled from all three items (*cánapa*, *patáta*, *maragiá*), while the subsequent tables (38-43) report the results for single items. Each table of results is followed by a descriptive table reporting the absolute values of each acoustic parameter for each vowel of the item.

With respect to secondary stress, table (44) reports the results pooled from the two items (*càtaláno, càtamaráno*), while the subsequent tables (45-48) report the results for single items. Each table of results is followed by a descriptive table reporting the absolute values of each acoustic parameter for each vowel of the item.

In the tables, the following abbreviations are used: A = antepenult, P = penult, F = final, PS = primary stress, SS = secondary stress. The vowels in the words *càtaláno* and *càtamaráno* are numbered 1, 2, 3 etc. from the first vowel to the last.

Overall, in the case of the items aimed at analyzing primary stress, out of a total of 90 realizations for each item (3 repetitions by 30 speakers) some had to be discarded because of mistakes or hesitation in the pronunciation. The discarded realizations were: 1 for *cánapa*, 4 for *patáta* and 12 for *maragiá*. In the case of the items aimed at analyzing secondary stress, out of a total of 90 realizations for each item (3 repetitions by 30 speakers) some had to be discarded because of mistakes or hesitation in the pronunciation or because secondary stress was deemed to be either not clearly detectable or not on the first syllable. The discarded realizations were: 19 for *càtaláno* and 18 for *càtamaráno*.

14.3.1 Results for primary stress

Shaded rows indicate that the main predictor *Stress* (stressed vowels *vs* unstressed vowels) significantly improves the model. All significant predictors are also included in the last column of each table labeled 'Significant variables'.

Table (36). Results for all *cánapa*, *patáta* and *maragiá* pooled together.

	Stressed vowel	**Unstressed vowel**	**Significant variables**	**Pairwise comparisons: stressed vowels**
Duration[124]	**139**	83.7	Stress, Stress*Stress_position, Age	A[125] > F (p = 0.02) A < P (p = 0.07) F < P (p < .0001)
Intensity	**75.5**	75.3	Stress, Stress*Stress_position	A < F (p = 0.82) A < P (p = 0.33) F > P (p = 0.12)
F0	153	**164**	Stress, Stress*Stress_position, Sex, Age	A < F (p = 0.002) A > P (p = 0.56) F > P (p < .001)
F1	**770**	698	Stress, Stress_position, Sex	
F2	**1393**	1387	Stress, Stress*Stress, Sex	A > F (p = 0.90) A > P (p < .001) F > P (p = 0.001)
Spectral tilt	-0.00803	**-0.00772**	Stress, Stress_position	

Table (37). Descriptive values of the vowels of *cánapa*, *patáta* and *maragiá* pooled together.

Vowel	**A**	**P**	**F**
Duration	96.5	99.9	110
Intensity	76.3	75.1	74.7
F0	156	149	178
F1	740	708	719

[124] In the case of duration, an exploratory analysis was also conducted for *cánapa*, *patáta* and *maragiá* pooled together applying z-scores to the data before the statistical analysis. However, in the analysis with the z-scores the p-values did not improved with respect to the standard analysis (see appendix 17), so it has been decided not to apply z-scores to the data in any of the analyses.

[125] In this column, A (antepenult) refers to the stressed vowel of *cánapa*, P (penult) refers to the stressed vowel of *patáta* and F (final) refers to the stressed vowel of *maragiá.*

F2	1365	1440	1362
Spectral tilt	-0.00774	-0.00783	-0.00790

Table (38). Results for *cánapa.*

	Stressed vowel	Unstressed vowels	Significant variables
Duration	**139**	83	Stress, Age
Intensity	**75.6**	74.6	Stress,
F0	147	**174**	Stress, Sex
F1	**805**	723	Stress, Sex
F2	**1424**	1361	Stress, Sex
Spectral tilt	-0.00837	**-0.00798**	Stress,

Table (39). Descriptive values of the vowels of *cánapa.*

	Vowels		
	A (PS)	**P**	**F**
Duration	139	65.8	100
Intensity	75.6	74.3	74.8
F0	147	156	192
F1	805	732	715
F2	1424	1430	1292
Spectral tilt	-0.00837	-0.00738	-0.00812

Table (40). Results for *patáta.*

	Stressed vowel	Unstressed vowels	Significant variables
Duration	**148**	84.1	Stress, Age
Intensity	**74.9**	74.7	
F0	143	**168**	Stress, Sex, Age
F1	**768**	693	Stress, Sex
F2	1339	**1342**	Sex
Spectral tilt	-0.00824	**-0.00787**	Stress, Sex

Table (41) Descriptive values of the vowels of *patáta.*

	Vowels		
	A	**P (PS)**	**F**
Duration	65.3	148	103

Intensity	75.9	74.9	73.4
F0	167	143	169
F1	676	768	710
F2	1300	1339	1383
Spectral tilt	-0.00761	-0.00824	-0.00812

Table (42) Results for *maragiá.*

	Stressed vowel	**Unstressed vowels**	**Significant variables**
Duration	**128**	84	Stress,
Intensity	76	**76.9**	Stress,
F0	**172**	149	Stress, Sex
F1	**732**	675	Stress, Sex
F2	1418	**1466**	Stress, Sex
Spectral tilt	-0.00740	**-0.00726**	

Table (43). Descriptive values of the vowels of *maragiá.*

	Vowels		
	A	**P**	**F (PS)**
Duration	82.3	85.8	128
Intensity	77.5	76.3	76.0
F0	152	146	172
F1	737	612	732
F2	1369	1563	1418
Spectral tilt	-0.00715	-0.00738	-0.00740

14.3.2 Results for secondary stress

Shaded rows indicate that the main predictor *Sec_stress* (1° vowel, i.e. secondary stressed vowel, vs 2° vowel, i.e. unstressed vowel) significantly improves the model. All significant predictors are also included in the last column of each table labeled 'Significant variables'.

Table (44). Results for *càtaláno* and *càtamaráno* pooled together.

	1° secondary stressed vowel	**2° unstressed vowel**	**Significant variables**	**Pairwise comparisons: secondary stressed vowels**
Duration	53.5	**61.2**	Sec_stress, Interval, Age	
Intensity	75.5	**76.3**	Sec_stress, Interval	
F0	**173**	162	Sex	
F0 (only females)	**188**	183	Sec_stress, Interval, Age	
F1	646	**697**	Sec_stress, Sex	
F2	**1498**	1402	Sec_stress, (almost Sex)	
Spectral tilt	**-0.00760**	-0.00762	Sec_stress, Sec_stress * Interval	ctl[126] < ctm (p = 0.058)

Table (45). Results for *càtaláno.*

	1° secondary stress vowel	**2° unstressed vowel**	**Significant variables**
Duration	55.7	**66.3**	Sec_stress,
Intensity	75.8	**76.9**	Sec_stress,
F0	**173**	163	Sex
F0 (only females)	**188**	180	Sec_stress, Age
F1	648	**688**	Sec_stress, Sex
F2	**1490**	1420	Sec_stress, (almost Sex)
Spectral tilt	-0.00776	**-0.00747**	

Table (46). Descriptive values of the vowels of *càtaláno.*

Vowels	**1 (SS)**	**2**	**3 (PS)**	**4**
Duration	55.7	66.3	173	97.6
Intensity	75.8	76.9	75.3	73.0

[126] 'Ctl' refers to the secondary stressed vowel of *càtaláno*, while 'ctm' refers to the secondary stressed vowel of *càtamaráno.*

F0	173	163	153	183
F1	648	688	747	564
F2	1490	1420	1364	1210
Spectral tilt	-0.00776	-0.00747	-0.00811	-0.00740

Table (47). Results for *càtamaráno.*

	1° secondary stress vowel	**2° unstressed vowel**	**Significant variables**
Duration	51.3	**56.3**	Sec_stress, Age
Intensity	75.2	**75.7**	
F0	**173**	160	Sex
F0 (only females	**189**	186	Age
F1	645	**705**	Sec_stress, Sex
F2	**1506**	1383	Sec_stress, (almost Sex)
Spectral tilt	**-0.00745**	-0.00775	

Table (48). Descriptive values of the vowels of *càtamaráno.*

Vowels	**1 (SS)**	**2**	**3**	**4 (PS)**	**5**
Duration	51.3	56.3	84.0	176	97.3
Intensity	75.2	75.7	75.5	74.7	73.0
F0	173	160	151	147	188
F1	645	705	761	804	554
F2	1506	1383	1415	1406	1172
Spectral tilt	-0.00745	-0.00775	-0.00736	-0.00845	-0.00765

14.4 Discussion of results

14.4.1 Discussion of results: primary stress

14.4.1.1 Duration

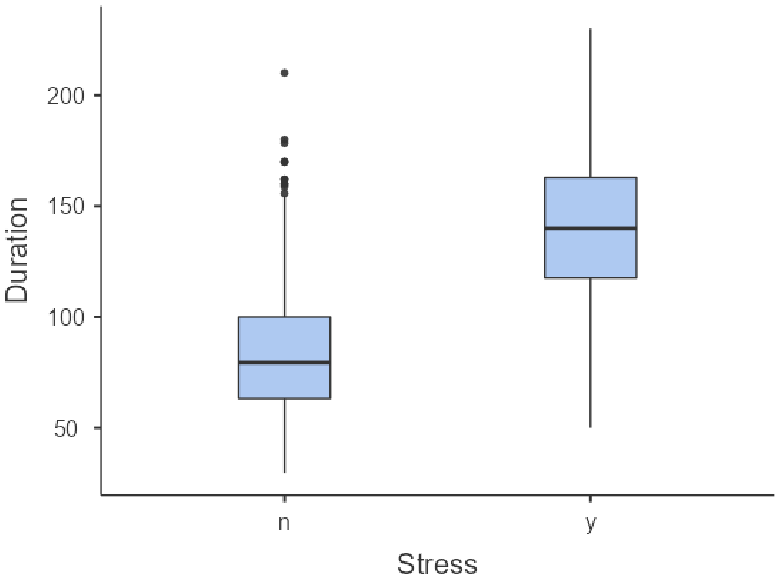
With respect to duration, the results of table (36) reporting the results for all three items pooled together (*cánapa, patáta*, *maragiá*) indicate that, overall, duration is significantly higher in the stressed vowels than in the unstressed vowels, and the same results are confirmed looking at the results by single items (tables 38, 40, 42). Furthermore, the results of (36) show that the interaction between *Stress* and *Stress_position* significantly improves the model, suggesting that duration is affected by stress differently in the different items. More specifically looking at the stressed vowels of the three items in tables (39), (41) and (43), it can be seen that the stressed vowel of *patáta* (in penultimate position) is the one which lengthens the most, 148 ms, followed by the stressed vowel of *cánapa*, 139 ms (in antepenultimate position), followed by the stressed vowel of *maragiá,* 128 ms (in final position). These results are in line with what is usually found in the phonological literature on the foot in Italian (see sub-chapter 3.2). The results of the pairwise comparisons in table (36) indicate that the difference in duration between the stressed vowel in *cánapa vs maragiá* ($p = 0.02$) and in *maragiá vs patáta* ($p < .0001$) are both significant, while the difference in *cánapa vs patáta* is not significant by a very low margin ($p = 0.07$). The latter is an unexpected result that might perhaps be due to the variability in the duration rates due to the high number of speakers.

Looking at the descriptive tables of single items (39, 41, 43), it can also be noted that in both *cánapa* (table 39) and *patáta* (table 41), the final unstressed vowel is always longer than the other unstressed vowel within each of the two words. This might be due to the effect of final lengthening, since all the target items were inserted at the end of the carrier sentence *Ha detto di nuovo X* 'He/She said X again' in order to be in accented position. However, the effect of final lengthening seems to have affected only unstressed vowels, but not the stressed vowel in *maragiá,* which still turns out to be shorter than the stressed vowels of *cánapa* and *patáta.*

Finally, the variable *Age* was also found to significantly improve the model with respect to duration. The regression coefficient shows an average increase in duration of 0.3361 ms for every additional year, suggesting that older speakers tend to have, overall, a lower speaking rate.

Overall, these results confirm duration as a reliable correlate of stress as was also found in other studies and they also confirm that the duration of the stressed vowel varies depending on its position, with the penultimate vowel longer than the antepenultimate vowel, in turn longer than the final vowel.

Figure (8). Box plots of the duration values for all three items pooled together (*cánapa, patáta*, *maragiá*). On the x-axis: y = stressed vowels n = unstressed vowels.



14.4.1.2 Intensity

Looking at table (36), which reports the results of all three items together, it can be seen that stressed vowels have an average higher intensity than unstressed vowels. Both *Stress* and the interaction *Stress*Stress_position* significantly improve the model, suggesting that the realization of intensity with respect to stress varies significantly between items. However, looking at the descriptive data of the single items (tables 39, 41, 43), it can be seen that intensity is higher in the stressed vowel only in *cánapa,* while in both *patáta* and *maragiá* intensity is higher in the first vowel, irrespective of stress position. If one looks at the descriptive values of intensity for all three items separately, it can be seen that in all items intensity is systematically higher in the first vowel, lower in the second vowel and even lower in the third vowel. The only minor exception is in the case of *cánapa,* in which the third vowel has slightly higher intensity than the second vowel (74.8 *vs* 74.3 respectively), both however have lower intensity than the first vowel (75.6). The same pattern is also present in the descriptive data of older studies, for example Bertinetto (1981: 254) reports the values of intensity for 3-syllable words with stress either on the antepenult, penult or final and it can be seen that in the vast majority of cases intensity is higher on the first vowel and declines gradually towards the third vowel, irrespective of stress position. Also Sulpizio and McQueen (2012) measuring amplitude in the first two vowels of words such as *cánapa* and *canále* found that amplitude was higher in the first vowel in both words. These results could be interpreted in two ways: either intensity can be considered a reliable correlate of stress only for *cánapa*, i.e. for words having stress on the first syllable, or intensity should simply be considered correlated with position, i.e. being higher at the left margin of the word and gradually decreasing towards the right. This decreasing pattern might perhaps be due to the fact the word beginning is physiologically associated with an increased vocal effort. Plag *et al.* (2011), found similar decreasing patterns towards the right for both F0 and intensity and attributed this trend to a steady decrease in subglottal pressure, thus corroborating the idea that also in the items tested here intensity variation should not directly be associated with stress.

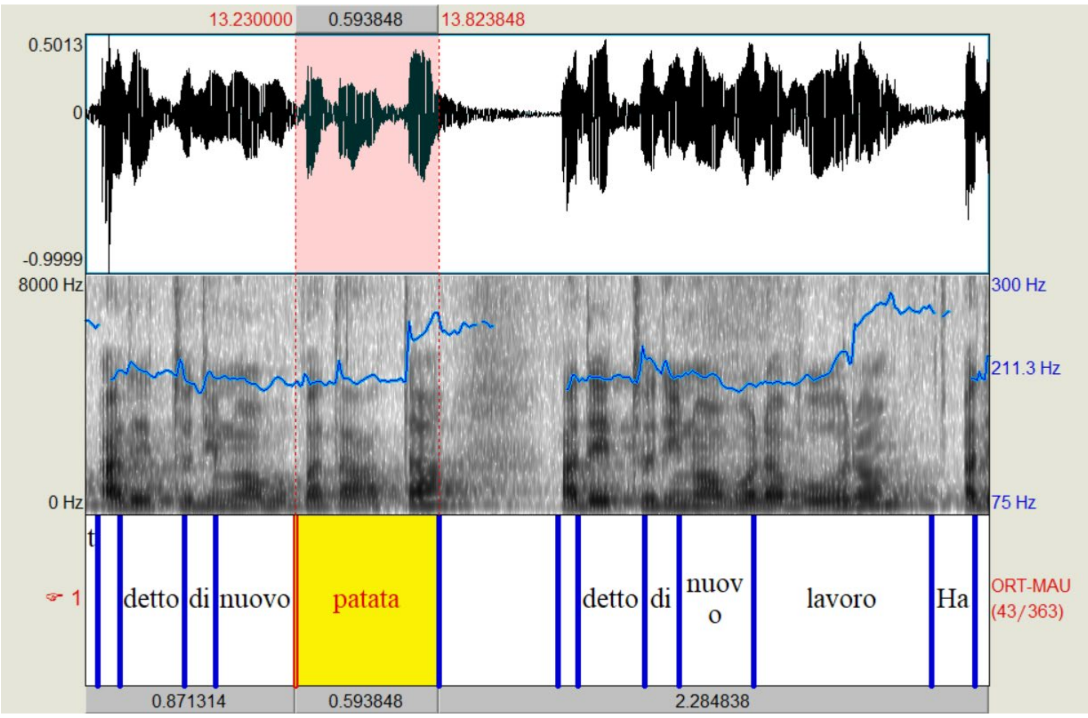
14.4.1.3 F0

With respect to F0, looking at table (36) reporting the results of the three target items together, it can be noted that, on average, F0 is lower in the stressed vowels than in the unstressed vowels. The model improves significantly adding *Stress* and also the interaction *Stress*Stress_position*, suggesting that the realization of F0 with respect to stress varies significantly between items. Looking at the descriptive data for single items (tables 39, 41, 43) it can be seen that F0 is lower on the stressed vowel only in *cánapa* and in *patáta* but not in *maragiá,* in which F0 gradually increases from the first to the third vowel, which has the highest F0. The same gradual increase from the first to the third vowel can also been observed in *cánapa.* A similar increase could also be attributed to *patáta,* in which however the penultimate stressed vowel breaks the rising F0 contour.

Somewhat similar results were also found in Italian by Eriksson *et al.* (2016) in which stressed vowels were associated with lower F0. The authors attributed this pattern possibly to a declarative F0 contour, in which the sentence accent (associated with the lowest F0 in a declarative sentence) anchors to the word stress. On this basis, also in the present study the lower F0 of the stressed syllables in *cánapa* and *patáta* could be associated with the fact that the sentence accent of a declarative sentence is anchored to the stress of the word in focus condition, which is in line with the intonational pattern expected from the used carrier sentence *Ha detto di nuovo X* 'He/she said X again', where X represents the target word. Conversely, the fact that F0 tends to rise towards the final vowel in all three words could be explained by the fact that the carrier sentences were read by the participants in a list, which meant that the participants first read the carrier sentence with an F0 contour typical of a declarative sentence, i.e. decreasing from left to right and reaching its lowest point on the stressed vowel of the target word (which, as can be seen from the carrier sentence mentioned above, was at the end of the sentence), then, when reaching the end of the sentence, the participants suddenly raised the F0, following a pattern typical of list-reading, in which F0 is raised at the end of one sentence of the list, giving rise to a ‘suspension’ before reading the next sentence in the list.

An example showing the typical F0 contour used in the experiment by most participants is given in figure (9), showing the F0 contour associated with the sentences *Ha detto di nuovo patata* followed by *Ha detto di nuovo lavoro* (the latter containing the filler word *lavóro* ‘job’), taken from the female participant A25.

Figure (9). F0 contour associated with *Ha detto di nuovo patata* followed by *Ha detto di nuovo lavoro* for female participant A25.



As can be seen from figure (9), the F0 contour in both sentences *Ha detto di nuovo patata* and *Ha detto di nuovo lavoro* tends to be rather flat or slightly decreasing throughout most of the sentences, (also a further slight decrease is visible in the stressed vowel of *patáta*), then F0 suddenly increases at the end of the sentence, mostly on the final syllable of both *patáta* and *lavóro.*

According to this interpretation, the fact that the word *maragiá* shows a gradual increase from the first to the third vowel, instead of showing a decrease in F0 on the stressed vowel as in *cánapa* and *patáta,* might be due to the strong influence of the list-reading pattern which triggers a sudden increase on the last vowel, irrespective of whether this is stressed or not.

Overall, F0 cannot thus be directly considered a correlate of stress in Italian, however the interaction of stress with accent might still signal the presence of stress, which is generally associated with the lowest F0, at least in declarative sentences like the ones used in this experiment.

It has to be noted, however, that through an impressionistic review of the F0 patterns used by the participants, the above described pattern, i.e. declarative + list-reading, is not always used in all cases, and the way in which stress interacts with F0 might change considerably depending on the used intonational contour, so that in order to understand the complex relationship between stress and accent more research is needed, analyzing stress in different intonational conditions, including unaccented conditions.

Finally, as expected, the variable *Sex* turns out to improve the model, due to the average higher F0 of the female participants. The variable *Age* is also significant, with a coefficient of -0.6329, indicating an average decrease in F0 for an increase of one unit in age. This might be due to the presence of a certain degree of correlation between the sex and the age of the participants, with older participants being mostly males, as can be inferred from the average age of the 13 male speakers being 44.1 years, while the average age of the 17 female speakers being 30.3 years.

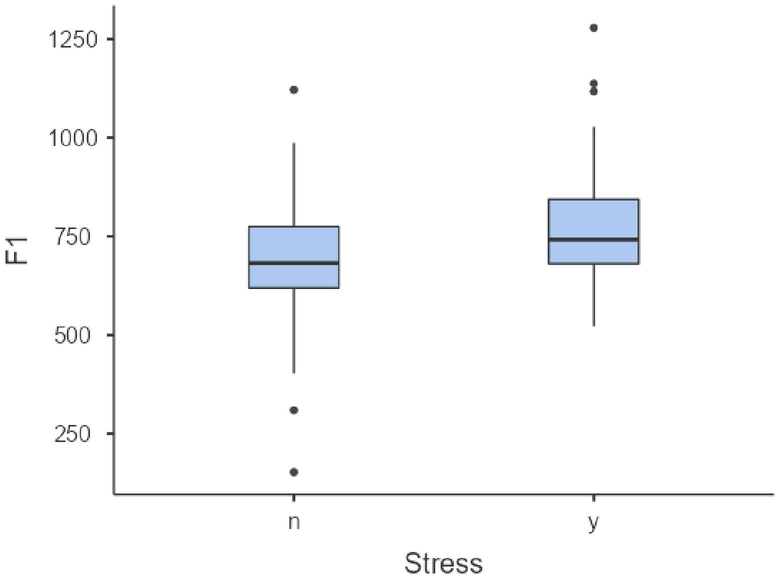
14.4.1.4 F1

Looking at table (36) with the results for all three items together, it can be seen that the variable *Stress* significantly improves the model with respect to F1, with F1 being higher in stressed vowels than in unstressed vowels. Since all the items contained the vowel [a] in all syllables, these results are in line with a more peripheral, i.e. lower, [a] in stressed position and a more centralized, i.e. higher, [a] in unstressed position. The interaction *Stress*Stress_position* does not seem to improve the model, suggesting no significant difference of the effect of stress on F1 depending on stress position. Looking at the results for single items (tables 38, 40, 42), it can be seen that *Stress* improves the model with respect to F1 in all three items. However, looking at the descriptive data for single items (tables 39, 41, 43) it can be seen that the stressed vowel has the highest F1 in *cánapa* and *patáta*, while in *maragiá* the highest F1 is on the antepenult (737 Hz) followed by the final (732 Hz). In spite of this unexpected result, the model for *maragiá* in table (42) still improves significantly adding the variable *Stress.* Furthermore, from a perceptual point of view, it is likely that, when speakers hear the word *maragiá*, what gives rise to the perception of stress is the comparison between the final syllable (732 Hz). and the penult, which has a considerably lower F1, i.e. 612 Hz. The considerably higher F1 also on the antepenult might be tentatively interpreted as due to the presence of a secondary stress (but see also the discussion on results concerning F1 and secondary stress in section 14.4.2.4).

As was the case for F0, also in the case of F1 *Sex* turns out to be a significant variable in all models, with females producing on average higher F1 than males.

Overall, as was the case for duration, also F1 can be considered a reliable correlate of primary stress in Italian, at least for the vowel [a], which has on average a higher F1 in stressed vowels than in unstressed vowels.

Figure (10). Box plots of the F1 values for all three items pooled together (*cánapa, patáta*, *maragiá*). On the x-axis: y = stressed vowels n = unstressed vowels.



14.4.1.5 F2

Looking at the table with the results for all items together (table 36), it can be seen that both *Stress* and *Stress*Stress_position* significantly improve the model, however the values of F2 are not in line with the expectations, i.e. stressed vowels have a higher F2 than unstressed vowels, while the contrary was expected. The inclusion of *Stress*Stress_position* also indicates significant differences with respect to the way in which the F2 values of stressed syllables change with respect to position. Looking at the results for single items (tables 38, 40, 42), it can be seen that the variable *Stress* improves the model only for *cánapa* and *maragiá*, but not for *patáta* (p = 0.870), and looking at the descriptive data for single items (tables 39, 41, 43), it can be seen that F2 has, again contrary to expectations, the highest value in the stressed vowel in *cánapa,* while in *patáta* and *maragiá* the stressed vowel has an intermediate value of F2 with respect to the other two unstressed vowels and no particular pattern can be established. As expected, *Sex* also turns out to be a significant variable, with female speakers producing on average higher F2 than male speakers.

Overall, on the basis of the inconsistency of these results, F2 for the vowel [a] cannot be considered a reliable correlate of primary stress.

14.4.1.6 Spectral tilt

Looking at the table with the results for all items together (table 36), it can be seen that *Stress* but not *Stress*Stress_position* significantly improves the model. However, the results indicate a higher value of spectral tilt in the unstressed vowel than in the stressed vowel. This is contrary to the expectations, which were to have a higher value of spectral tilt in the stressed vowel, indicating a less steep tilt with respect to the relationship between intensity and frequency, i.e. indicating that intensity decreases less at higher frequency in a stressed vowel than in an unstressed vowel. These unexpected results are also confirmed looking at the tables with the results for single items (38, 40, 42) and also at the descriptive tables for single items (39, 41, 43). In all items, the stressed vowel is always associated with the lowest value of spectral tilt.

Similar anomalous results were also found by Aronov and Schweitzer (2016) for German (see chapter 13). The authors measured the same type of spectral tilt used here (the slope of a linear regression line in the frequency spectrum between 1 and 5000 Hz) on primary stress in German and also found that lower values of spectral tilt were associated with the stressed vowels. As Aronov and Schweitzer note, these results might be an indication that the claim that stressed vowels have a less steep slope might be valid only at lower frequencies, which was also confirmed by their second analysis in which they measured spectral tilt in lower frequency bands. The results found in the present study corroborate thus these conclusions also in the case of Italian primary stress.

14.4.2 Discussion of results: secondary stress

14.4.2.1 Duration

Looking at table (44) with the results for both items (*càtaláno* and *càtamaráno*) pooled together, it can be seen that the variable *Sec_stress* improves the model with respect to duration, however, contrary to the expectations, the first vowel, i.e. the vowel which is supposed to bear a secondary stress, has on average a lower value for duration than the second unstressed vowel. These results are confirmed also looking at the tables reporting the results for single items (tables 45, 47) and those reporting the descriptive data of single items (tables 46, 48). More specifically, from the descriptive tables it can be seen that, in both *càtaláno* and *càtamaráno*, duration increases gradually from the first syllable to the syllable bearing primary stress and finally decreases again in the post-tonic final syllable. The same patterns can also be found in the descriptive data of other studies that report the duration values for long words with primary stress on the right margin and with the same vowel in all syllables, such as in the words *catamaráno* and *magazziniére* in Brugnoli (2019: 73) or the word *pomodóro* in Bertinetto (1976: 218). In Bertinetto (1976)'s data, this gradual increase in duration towards primary stress on the right is found less consistently in words that do not have the same vowel in each syllable, likely due to the fact that different vowels have different inherent duration.

Overall, these results support the conclusion that in *càtaláno* and *càtamaráno,* and likely in all words with a similar structure, duration is correlated with position and primary stress rather than with secondary stress, i.e. duration increases gradually from the leftmost vowel to the vowel bearing primary stress.

14.4.2.2 Intensity

Looking at table (44) with the results for both items (*càtaláno* and *càtamaráno*) together, it can be seen that the variable *Sec_stress* improves the model with respect to intensity, however intensity is on average higher on the second vowel than on the first vowel.

Looking at the tables with the descriptive data for the two items (46, 48) it can be seen that in both items intensity has the highest value on the second vowel and then progressively decreases towards to end of the word. This pattern seems to recall the one found in the items aimed at analyzing primary stress (*cánapa*, *patáta*, *maragiá*), in which intensity was found to have systematically the highest value on the first syllable and then to decrease towards the final syllable. It still remains unclear why in *càtaláno* and *càtamaráno* it is the second vowel and not the first to have the highest intensity, however it has to be noted that, looking at the results for single items, the difference between the first and the second syllable turns out to be significant only in *càtaláno* but not in *càtamaráno*, so that perhaps the same conclusions that were drawn for *cánapa*, *patáta* and *maragiá* could also be drawn for *càtaláno* and *càtamaráno*, i.e. intensity has the highest value at the left margin of the word and then gradually decreases towards the right. As in the case of *cánapa*, *patáta* and *maragiá*, this pattern might be explained by the increased vocal effort which is exerted at the beginning of the word.

14.4.2.3 F0

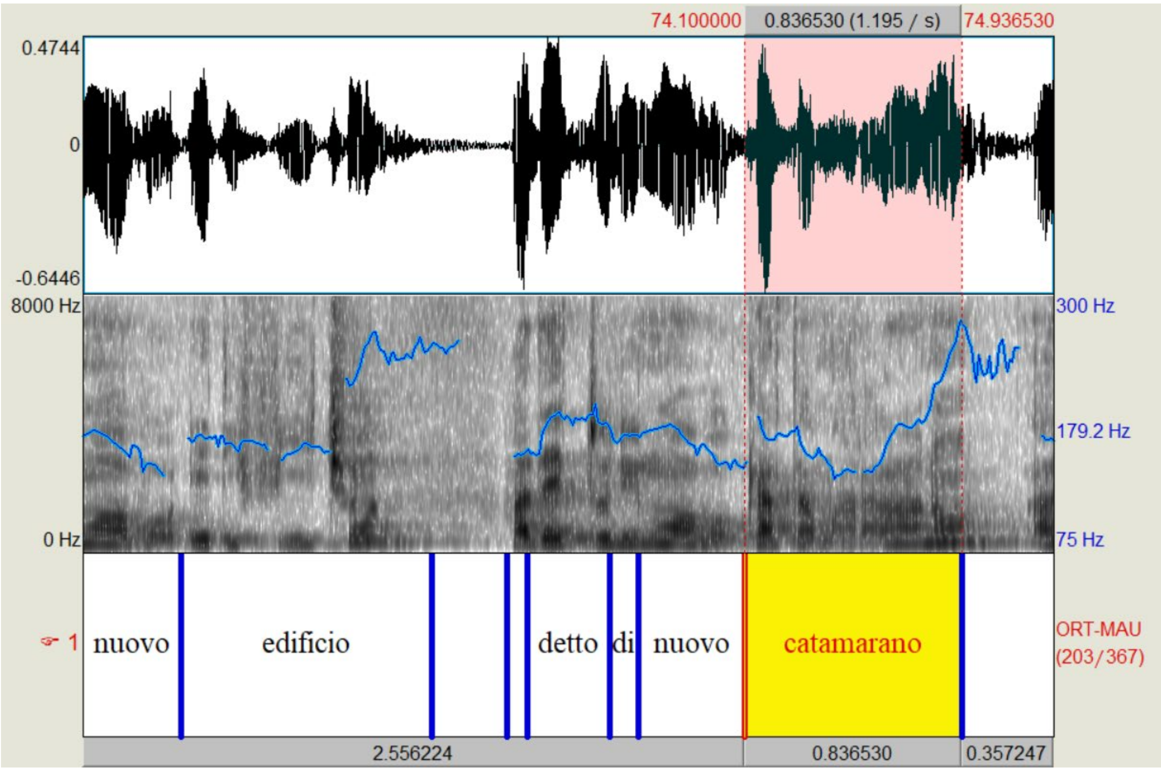
Looking at table (44) with the results for both items (*càtaláno* and *càtamaráno*) together, it can be seen that F0 is higher in the first vowel than in the second vowel, however the variable *Sec_stress* does not improve the model, so that the difference between the two cannot be considered significant.

However, since the variable *Sex* turned out to be significant, as was often the case for measurements of F0 and formant frequencies, the fact that *Sec_stress* does not improve the model might be due to the high variability in F0 due to the significantly different F0 values of male and females participants. In order to test this hypothesis, a second analysis has been conducted using only the data from female participants (who were 17 out of 30 participants). The results of the new analysis are reported in the rows lables 'F0 (ony females)'. As can be seen in table (44), reporting the results for both items, when taking the data from male participants out the analysis, *Sec_stress* significantly improves the model. In this new analsysis*, Sec_stress* turns out to improve the model also for the single item *càtaláno*, but not for the single item *càtamaráno.*

Looking at the descriptive tables for single items (46, 48) it can be seen that overall F0 in the new analysis (as well as in the previous analysis) is higher on the first vowel, then gradually decreases reaching its lowest value on the primary stressed vowel and finally suddenly rises again on the last vowel.

This pattern is very much in line with the pattern that was found with respect to *cánapa*, *patáta* and *maragiá* (see figure 9), i.e. it seems to reflect a declarative intonational contour associated with the carrier sentence *Ha detto di nuovo X* 'He/She said X again', in which F0 starts high and then decreases, reaching its lowest value around the stressed syllable of the target word, which is in accented position, and finally suddenly increases because of the intonational contour associated with a list-reading pattern, which causes a final increase in F0 before reading the next element in the list. However, unlike in the case of the primary stressed items, in the case of *càtaláno* and *càtamaráno*, from an impressionistic review of the spectrograms, it seems that the overall decreasing trend of F0 of the carrier sentence is blocked by the secondary stressed vowel, in which F0 rises slightly and then decreases again in the second unstressed vowel. An example of this pattern can be seen in figure (11), taken from female speaker A28.

Figure (11). F0 contour associated with *Ha detto di nuovo catamarano* for female participant A28.



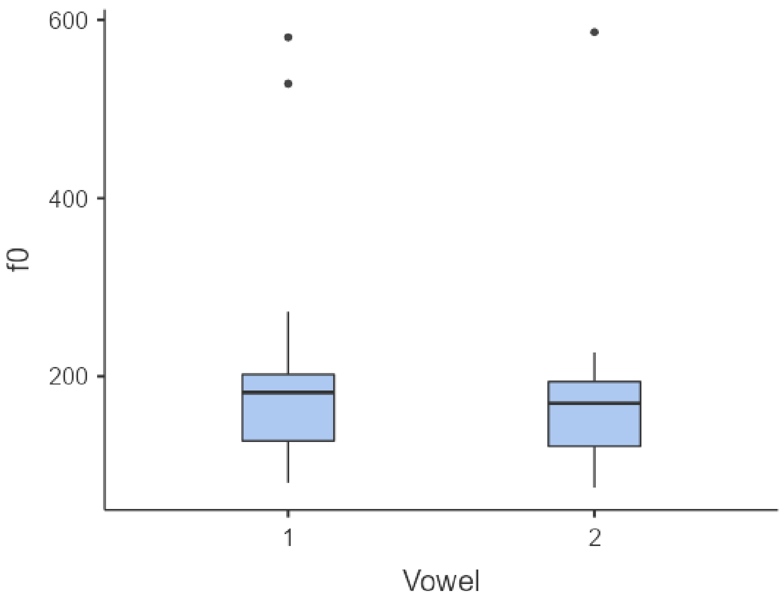
It has to be noted that this rise in F0 on the first vowel of a target word seems not to be present in target words that are not supposed to have a secondary stress on the first syllable, as can be seen in figure (9) above, in which both *patáta* and *lavóro* have a primary stress on the penultimate syllable and could not thus have a secondary on the first syllable, since this would create a stress clash. Indeed, in both *patáta* and *lavóro*, a rise in F0 on the first vowel of the target word in comparison to the F0 contour on the vowels preceding the target word is not observed.

On the basis of these results it might be possible to tentatively conclude that the overall decreasing F0 contour anchors to the secondary stress vowel, by undergoing a sudden increase, and then decreases again towards the primary stressed vowel. However, in order to confirm this hypothesis, an analysis in which the F0 values of the final vowel(s) of *nuóvo*, i.e. the word preceding the secondary stressed vowel, should be carried out, in order to check whether in the majority of cases there is a statistically significant increase in F0 on the secondary stressed vowel of the target words in comparison to the final vowel(s) of the preceding word *nuóvo*.

Furthermore, it still remains possible that the observed rise in F0 on the first vowel of the target words might actually occur in the case of all types of words, irrespective of the presence of secondary stress, so that this F0 rise might be interpreted as correlated with the onset of a word in accented position, rather than with a secondary stress on the first syllable of a word. In order to test this hypothesis in more detail, a more extensive study should be conducted, also analyzing whether the observed rise in F0 in comparison to the previous syllables actually happens only in words deemed to have a secondary stress on the first syllable.

Since no interaction between *Sec_stress* and *Interval* was found, this suggests that the secondary stress vowel does not differ significantly in F0 between *càtaláno* and *càtamaráno,* suggesting no influence of the inter-stress interval on the realization of secondary stress.

Figure (12). Box plots of the F0 values for the two items pooled together (*càtaláno*, *càtamaráno*). On the x-axis: 1 = first stressed stressed vowels, 2 = second unstressed vowels.



14.4.2.4 F1

Looking at table (44) with the results for both items (*càtaláno* and *càtamaráno*) together, it can be seen that the variable *Sec_stress* improves the model, however F1 turns out to be higher on the second vowel than in the first vowel, suggesting a lower/more peripheral [a] on the second syllable, while the expectations were to find a lower/more peripheral [a] on the first secondary stressed syllable.

Looking at the descriptive tables for single items (45, 47) it can be seen that in both *càtaláno* and *càtamaráno* F1 gradually increases from the first vowel to the vowel bearing primary stress and then suddenly drops in the post-tonic vowel. This pattern is exactly the same as the one found for duration, with the caveat that the post-tonic drop in these cases is certainly also influenced by the fact that the post-tonic vowel in both items is [o] instead of [a]. Since [o] is a vowel higher than [a], it is also expected to have an F1 lower than [a]. Still, this suggests that F1 in pre-tonic syllables, at least in the type of words analyzed here, is correlated with position. It might thus be possible to claim that, in this type of words, F1 and duration are somewhat correlated, perhaps due to the fact that a longer vowel tends to be more clearly articulated, i.e. produced more peripherally, which in the case of [a] corresponds to an increase in F1. On the other hand it is also clear that F1 and duration retain a certain degree of independence, since they do not seem to be correlated in the three items aimed at analyzing primary stress (see results for *cánapa*, *patáta* and *maragiá* in 14.4.1).

14.4.2.5 F2

Looking at table (44) with the results for both items (*càtaláno* and *càtamaráno*) together, it can be seen that the variable *Sec_stress* improves the model with respect to F2. However, contrary to the expectations, F2 is higher in the first vowel and lower in the second vowel. Looking at the descriptive tables for single items (46, 48), it can be seen that in the case of *càtaláno* F2 decreases gradually from the first to the last syllable, as is the case of *càtamaráno,* in which F2 also seems to gradually decrease from the first to the last syllable, although with a slight increase on the third syllable. Ignoring the values of F2 for the last vowel, which are influenced by the fact that the vowel is [o] rather than [a], it could be affirmed that the vowels in *càtaláno* and *càtamaráno* tend to become more peripheral, i.e. more back, going from the first vowel to the primary stressed vowel. This is exactly the same pattern found for F1 described above, in which the values of F1 suggest that the vowels in *càtaláno* and *càtamaráno* tend to become more peripheral, i.e. lower in this case, going from the first vowel to the primary stressed vowel.

14.4.2.5 Spectral tilt

Looking at table (44) with the results for both items (*càtaláno* and *càtamaráno*) together, it can be seen that the variable *Sec_stress* and also its interaction with *Interval* improves the model with respect to Spectral tilt. Furthermore, the values of spectral tilt are according to expectations, i.e. a higher value of spectral tilt, indicating a less steep tilt, is found in the first vowel, the one which is supposed to bear a secondary stress, while a lower value of spectral tilt, indicating a steeper tilt, is found in the second unstressed vowel. However, the variable *Sec_stress* does not improve the model in the results of the single items (tables 45, 47) perhaps due to the effect of the reduced size of the dataset for single items. Furthermore, looking at the descriptive tables for *càtaláno* and *càtamaráno* (46, 48), it can be seen that in *càtaláno* the spectral tilt value is higher (less negative) in the second vowel while in *càtamaráno* the spectral tilt value is higher (less negative) in the first vowel (this difference might explain why the interaction between *Sec_stress*Interval* improves the model). It might perhaps be possible to claim that, since spectral tilt is higher in the first vowel of *càtamaráno,* this parameter might be considered a correlate of secondary stress only in this word. However, besides the fact that the variable *Sec_stress* does not improve the model for the single word *càtamaráno*, it should also be noted that in the items aimed at analyzing primary stress (*cánapa*, *patáta* and *maragiá*) spectral tilt was systematically found to have a lower value (i.e. more negative) in the primary stressed vowels than in the unstressed vowels, and the same is found in the case of *càtaláno* and *càtamaráno*, if one compares the primary stressed vowels with the other vowels. On this basis, if in a primary stressed vowel spectral tilt has a lower value in comparison to an unstressed vowel, also a secondary stressed vowel would be expected to have a lower value of spectral tilt in comparison to an unstressed vowel. However, the first vowel of *càtamaráno* was found to have a higher value of spectral tilt in comparison to the following unstressed vowel.

On this basis, spectral tilt cannot be considered a clear correlate of secondary stress in Italian.

14.5 Conclusions

With respect to primary stress, analyzed in the three items *cánapa*, *patáta* and *maragiá*, the results of this production experiment confirm duration as a reliable correlate of primary stress in Italian, confirming also that the duration of the stressed vowel varies depending on its position within the word, with the penultimate vowel longer than the antepenultimate vowel and the antepenultimate vowel longer than the final vowel.

F1 is the only other parameter besides duration that, on the basis of the results, can be clearly considered a correlate of primary stress, since it is on average higher in the stressed vowel than in the other vowels of the three items, meaning that [a] is articulated as lower, i.e. more peripheral, in stressed position than in unstressed position. The only minor exception is *maragiá,* in which F1 is slightly higher in the first vowel than in the third vowel, suggesting perhaps the presence of secondary stress on the first vowel.

On the contrary, F2, which was expected to be lower in the stressed vowel, was found to be rather inconsistent, so that it cannot be clearly considered to be a correlate of primary stress.

Intensity was found to gradually decrease from the left margin of each word towards the right margin, suggesting that this trend might be due to the effect of the higher subglottal pressure at word onset which gradually declines towards the end of the word.

F0 was also found to gradually decrease from the left margin of each word towards the right margin, with a sudden increase close to the last vowel. This pattern can be interpreted as due to a declarative downwards pattern followed by a sudden rise typical of a list-reading pattern, in which F0 is increased at the end of a sentence before reading the next sentence in the list. However, since F0 generally reaches its lowest value on the stressed vowel of the word in focus condition, although F0 cannot be directly considered a correlate of primary stress in Italian, it might still be said to signal the presence of primary stress, at least in the specific prosodic context analyzed here, i.e. a declarative intonational contour.

With respect to spectral tilt, it was found to have values opposite to the expectations in all cases, i.e. it was found to have higher values, indicating a less steep tilt, in the unstressed vowels rather than in the stressed vowels. On this basis, the measure of spectral tilt used here (regression line between intensity and frequency in the frequency spectrum between 1 and 5000 Hz) cannot be considered a reliable acoustic correlate of primary stress.

Concerning the question of whether the acoustic correlates of stress vary between the antepenult, penult and final syllable, the only difference that was found concerns duration, which, as mentioned above, is higher in the stressed vowel in penultimate position, followed by the stressed vowel in antepenultimate position, followed by the stressed vowel in final position. None of the investigated acoustic parameters was found to be a correlate of stress only in a specific stress position, i.e. on a specific syllable within the word.

With respect to secondary stress, measured in the two items *càtaláno* and *càtamaráno*, duration was found to gradually increase from the first vowel towards the vowel bearing primary stress in the penultimate syllable, so it could be considered correlated with position rather than with secondary stress.

Intensity, very similarly to what was found in the items aimed at analyzing primary stress, was found to be higher on the left margin of the word and then to gradually decrease towards the right margin. Also in this case, this trend might be explained by the higher subglottal pressure at word onset which gradually declines towards the end of the word.

F0 was found to follow a pattern like the one found in the items aimed at analyzing primary stress, i.e. it gradually decreases from the beginning of the carrier sentence to the primary stressed vowel of the target word then undergoes a sudden increase close to the last vowel of the target word. As already mentioned above, this pattern can be interpreted as due to a declarative downwards pattern followed by a sudden rise typical of a list-reading pattern, in which F0 increases at the end of a sentence before reading the next sentence in the list. However, unlike in the case of the items with only primary stress, in the case of the items with a secondary stress on the first vowel, there seems to be an increase in F0 on the first vowel of the target words in comparison to the vowels preceding the target word, suggesting that the downwards F0 contour anchors to the secondary stressed vowel of the taget word by undergoing a sudden increase and then decreasing again. This rise in F0 might thus be tentatively interpreted as due to the presence secondary stress. These results, however, can be considered valid only for words in accented conditions and cannot be generalized to words in unaccented condition.

F1 was found to follow a pattern similar to duration, i.e. it gradually increases from the first vowel to the primary stressed vowel in the same way that duration did. The fact that both duration and F1 show this pattern suggests that they might be to a certain extent correlated. Namely, producing a longer vowel [a] might also have the effect of producing a lower/more peripheral [a], which corresponds to a higher F1.

Also F2 was found to follow a pattern similar to F1, i.e. it decreases gradually from the first vowel to the primary stressed vowel, indicating that the vowels [a] are produced more back/peripheral the closer they are to the primary stressed syllable.

Overall both F1 and F2 indicate that the vowels [a] in *càtaláno* and *càtamaráno* are progressively articulated more peripheral (lower and more back) the closer they get to the primary stressed syllable, starting from the left margin.

Spectral tilt was found to be inconsistent, with a higher value in the first vowel only of *càtaláno*. However this value in the first vowel, besides being in contrast with what was found in the case of primary stress, i.e. lower values of spectral tilt in the stressed vowel, was not found to be statistically significant in comparison to the value in the second syllable, so that the type of spectral tilt measured in this study cannot be considered a reliable correlate of secondary stress.

Overall, no reliable correlate of secondary stress could be found for the words *càtaláno* and *càtamaráno*. The results suggest however that F0 might perhaps anchor to an initial secondary stressed vowel of a word in accented condition, athough it is not clear whether this happens also in the case of other words that are in different prosodic conditions.

Since F0, which is the only parameter that could tentatively be considered a correlate of secondary stress, did not differ significantly between the secondary stressed vowels of the two target words, as a consequence, nothing can be said concerning the research question of whether secondary stress is manifested more prominently in words with a longer inter-stress interval.

15 Experiment on the acoustic correlates of stress in German

15.1 Research questions

The following experiment is aimed at detecting the acoustic correlates of primary and secondary stress in German.

With respect to primary stress, most studies point to duration as the strongest correlate of primary stress. The second strongest correlate seems to be represented by formant frequencies F1 and F2. Intensity has been found to correlate with stress only in a minority of studies, while F0 does not seem to be directly related to stress, rather to the intonational contour. Spectral tilt remains understudied as a correlate of primary stress in German, and in one study (Aronov and Schweitzer 2016) it has given contrasting results depending on the type of measurement used.

With respect to secondary stress, no reliable correlate has been identified so far. Two studies on Austrian German (Moosmüller 2007, El Zarka *et al.* 2017) suggest a lower F1 for the vowel [a] as a possible correlate, while one study on German spoken in Germany (Jessen 1993) suggests that duration of tense vowels in words with an σ̀σσ́ structure could be a potential correlate.

The present experiment is thus aimed at either confirming or disproving previous results with respect to the acoustic correlates of primary and secondary stress and possibly to single out new acoustic correlates.

Furthermore, some external variables which might play a role in the way stress is realized are also taken into consideration.

In the case of primary stress, one variable that is taken into account in the present study is polysyllabic shortening, i.e. the tendency for syllables or their vowels to reduce in duration as a function of the number of syllables in a word, so that longer words tend to have shorter syllables or vowels. This phenomenon has been found to play a role in different languages, such as English (White and Turk 2010) and Spanish and English (Gibson and Bernales 2020) with respect to syllable duration, and Arabic (Mashaqba and Huneety 2023) with respect to vowel duration. With respect to German, to my knowledge, this phenomenon has not been widely investigated. One study on German (Siddins *et al.* 2014) analyzed the opposition [zakt] (1 syllable) *vs* [zaktə] (2 syllables) and found no effect of polysyllabic shortening neither with respect to vowel duration nor with respect to F1 of the vowel, which was the other investigated parameter. On this basis, the phenomenon of polysyllabic shortening and its interaction with stress will be further investigated in the present experiment.

With respect to secondary stress, one issue which has not been investigated so far is whether secondary stress might be realized as more prominently (or in a different way) depending on the length of the inter-stress interval, i.e. depending on the distance in terms of number of syllables before primary and secondary stress. Although to my knowledge no study has been carried out on German, a piece of evidence concerning this phenomenon comes from Bertinetto and Loporcaro (2005)'s study in Italian. More specifically, as explained more in detail in chapter 3, Bertinetto and Loporcaro note that in Italian the retention of lax vowels in unstressed position in compounds might be interpreted as due to the presence of a secondary stress, e.g. [ˌpɔrtaomˈbrɛlli] instead of [portaomˈbrɛlli], and they note that the likelihood to retain the lax vowel increases with the inter-stress interval, supporting the idea that perhaps secondary stress is realized more prominently as a function of the length of the inter-stress interval between secondary and primary stress. For this reason, besides analyzing at the general level which are the acoustic correlates of secondary stress in German, the issue of whether secondary stress is manifested more prominently by increasing the inter-stress interval will also be investigated.

The research questions that will be addressed in this experiment are thus summarized in (56).

(56) Research questions on the acoustic correlates of primary and secondary stress in Italian.

a. What are the acoustic correlates of primary stress?

b. Does polysyllabic shortening occur in German and does it consequently affect the acoustic correlates of stress, above all duration?

d. What are the acoustic correlates of secondary stress?

e. Are the acoustic correlates of secondary stress manifested more prominently or differently depending on the length on the interval in terms of syllables between primary and secondary stress?

15.2 Methodology

15.2.1 Participants

30 native German speakers were recruited to participate in a production experiment. These participants are the same that took part in the nonce word experiment in chapter (7). The experiment on the acoustic correlates of stress took place immediately after the nonce word experiment. The data concerning the participants presented in chapter (7) are thus reported here again.

The participants are 23 females and 7 males, with an age range of 21-48 years and a mean age of 26.8. The participants are mostly in the range 21-30 years old, with only 3 participants being 37, 42 and 48 years old. The vast majority of the participants were recruited among students at the University of Marburg.

With respect to the place of origin, the participants come from different *Länder* (states) of Germany, mostly from the centre/west part of Germany, namely: 7 from Hessen, 6 from Baden-Württemberg, 5 from Bayern, 5 from Nordrhein-Westfalen, 4 from Niedersachsen, 1 from Sachsen, 1 from Sachsen-Anhalt and 1 from Mecklenburg-Vorpommern.

All participants were also asked to indicate whether they were bilingual (i.e. whether they spoke a second language natively, besides German) and whether they actively spoke a dialect. 3 participants stated that they spoke a dialect.

The relevant information about the participants is summarized in appendix (2).

Figure (13). Map of the places of origin of the German participants by state (*Land*).

15.2.2 Items

In order to analyze the acoustic correlates of primary stress, two words were chosen, i.e. *Pápa* ‘dad’ and *Pánama* ‘Panama (country name)’. Both target words contain the vowel /a/ in all syllables in order to reduce the variability related to vowel quality for the acoustic parameters when comparing stressed and unstressed vowels, especially with respect to duration and formant frequencies, both of which vary strongly depending on the type of vowel.

The target word *Pá.pa* consists of two syllables, while the target word *Pá.na.ma* consists of three syllables. The variability with respect to word length in terms of number of syllables was added in order to investigate the possible effect of polysyllabic shortening and its interaction with stress.

In order to analyze the acoustic correlates of secondary stress, two words were chosen, i.e. *Fànatísmus* ‘fanaticism’ and *kàtalysíeren* ‘catalyze’. Both words contain the vowel /a/ in the first two syllables, which are the target syllables, in order to reduce the variability related to vowel quality when comparing secondary stressed vowels and unstressed vowels.

Both *Fànatísmus* and *kàtalysíeren* bear primary stress on the penultimate syllable and are deemed to bear a secondary stress on the first syllable, based on the assumption that German has a directionality of secondary stress from left-to-right (see sub-chapter 4.4), i.e. secondary stress is placed on the first syllable in a word like *(kà.ta).ly.síe.ren*,[127] building a disyllabic trochaic foot on the left and leaving a syllable unparsed on the right before primary stress. In the case of (*Fà.na).tís.mus,* assuming the formation of a disyllabic trochaic foot, secondary stress can only fall on the first syllable, since it would otherwise incur in a stress clash with the primary stressed syllable, which is usually thought not to be possible in the case of non-compound words in the stress system of German.

The two words with secondary stress on the first syllable differ in the inter-stress interval, i.e. in the number of syllables that separate the primary stressed syllable and the secondary stressed syllable. Namely, *Fà.na.tís.mus,* has one unstressed syllable between primary and secondary stress, while *kà.ta.ly.síe.ren,* has two unstressed syllables between primary and secondary stress. The variable of the inter-stress interval was added in order to investigate the research question of whether the acoustic correlates of secondary stress are manifested more prominently or differently in words with a longer inter-stress interval.

All items used in the experiment are reported in table (49).

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[127] In German, the digraph <ie> in the primary stressed syllable represents the nucleus of only one syllable, namely the long vowel [i:].

Table (49). Items used to analyze the acoustic correlates of primary and secondary stress in German.

Level of stress investigated	**Items**	**Notes**
Primary stress	*Pápa, Pánama*	The items differ in the number of syllables
Secondary stress	*Fànatísmus*, *kàtalysíeren*	The items differ in the length of the inter-stress interval

15.2.3 Acoustic parameters

Six acoustic parameters were analyzed in the target vowels as possible acoustic correlates of either primary or secondary stress: vowel duration (ms), average intensity (db), average F0 (Hz), formant frequencies F1 and F2 calculated at midpoint (Hz), and spectral tilt (db/Hz), which was calculated through the 'Report spectral trend' function in *Praat*, which computes linear regression between intensity and frequency in a frequency spectrum comprised between 1 and 5000 Hz and returns as output the value of the slope expressed in db/Hz (the returned slope has always a negative value, since the relationship between intensity and frequency is inversely proportional).

With respect to the comparison between (primary or secondary) stressed vowels and unstressed vowels the expectations are different for the various parameters. Duration, intensity and F0 are expected to be higher in the stressed vowel. F1 is also expected to be higher in the stressed vowel, indicating a lower/more peripheral [a]. With respect to F2, Jessen (1993)'s data for stressed and unstressed vowels [a] in words with an σσσ́ structure suggest overall a higher F2 in stressed vowels in comparison to unstressed vowels. However, the data in Dogil and Williams (1999) suggest the opposite for the string of reiterated speech *dadadadáda* (based on the word *Liliputáner*), i.e. their data indicate lower F2 in stressed [a] with respect to unstressed [a]. El Zarka *et al.* (2017) also found F2 in the vowel [a] to be moderately lower in stressed position, however their study was done on Austrian German, so their data cannot be directly generalized to the data in the present study. Overall, for the present study, as working hypothesis, F2 will be expected to be higher in the stressed vowel [a] than in its unstressed counterpart, based on the results of Jessen (1993), since the structure of the items used in Jessen's experiment (σσσ́) is more similar to the structure of the items used here than those in Dogil and Williams (1999)'s experiment (σσσσ́σ).

Spectral tilt, which has always negative values, is expected to have higher values (i.e. less negative, closer to 0) in the stressed vowel, indicating a less steep tilt, i.e. indicating that intensity decreases less at higher frequencies in a stressed vowel than in an unstressed vowel, for which a lower value (more negative) is expected, indicating a steeper tilt. One example with respect to the expectations for spectral tilt would be to have a stressed vowel with a value of -00724 and an unstressed vowel with a value of -00765.

15.2.4 Procedure

The 4 target words (2 for primary stress and 2 for secondary stress) were inserted in a list together with filler words. Each word of the list was inserted into the carrier sentence *Sie hat schon wieder X gesagt* 'She said X again', where X represents a target word or a filler word. The carrier sentence was used in order to make sure that the target words were in accented position and also to have all target words inserted in the same prosodic context. The items in the list were pseudo-randomized.

Each participant read aloud the list three times in a soundproof cabin and was recorded using a *Sennheiser* K6 microphone with a *Sennheiser* ME66 capsule. Recordings were sampled at 44.1 kHz/16 bit.

All recordings were manually transcribed and automatically segmented using the *WebMaus* software (Schiel 1999). The segmentation obtained through *WebMaus* was then manually corrected, following the criteria discussed in Turk *et al.* (2006). Overall, the segmentation for *Fànatísmus* was not problematic. In the case of *Pápa*, *Pánama* and *kàtalysíeren*, the stop consonants [p] and [k] at the beginning of the word were characterized by aspiration in the form of multiple bursts after the release of the consonant and between the onset of voicing of the following vowel. In accordance with the criteria indicated in Turk *et al.* (2006), these bursts were segmented as part of the following vowel rather than as part of the preceding stop. An example of the segmentation of the first sequence [pa] in *Pápa* and [ka] in *kàtalysíeren* is given in figure (14) and (15), respectively.

Figure (14). Segmentation of the first sequence of [pa] in *Pápa* as pronounced by female speaker D13.

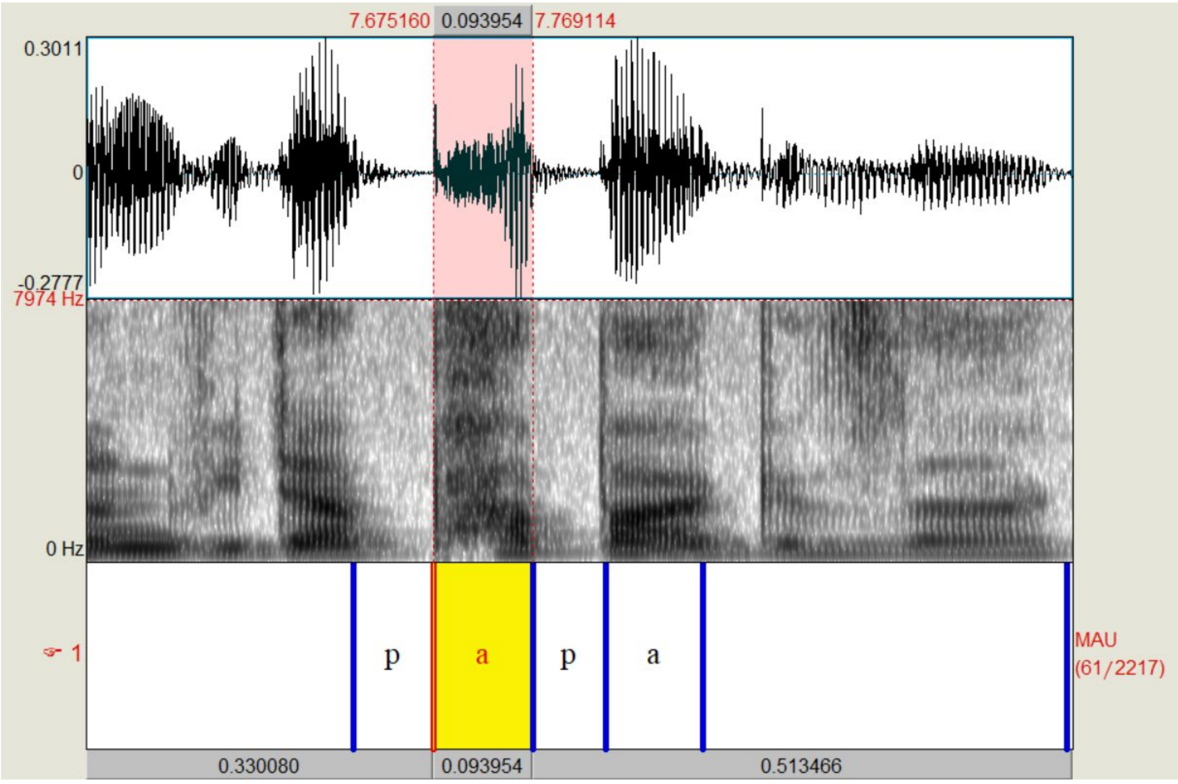
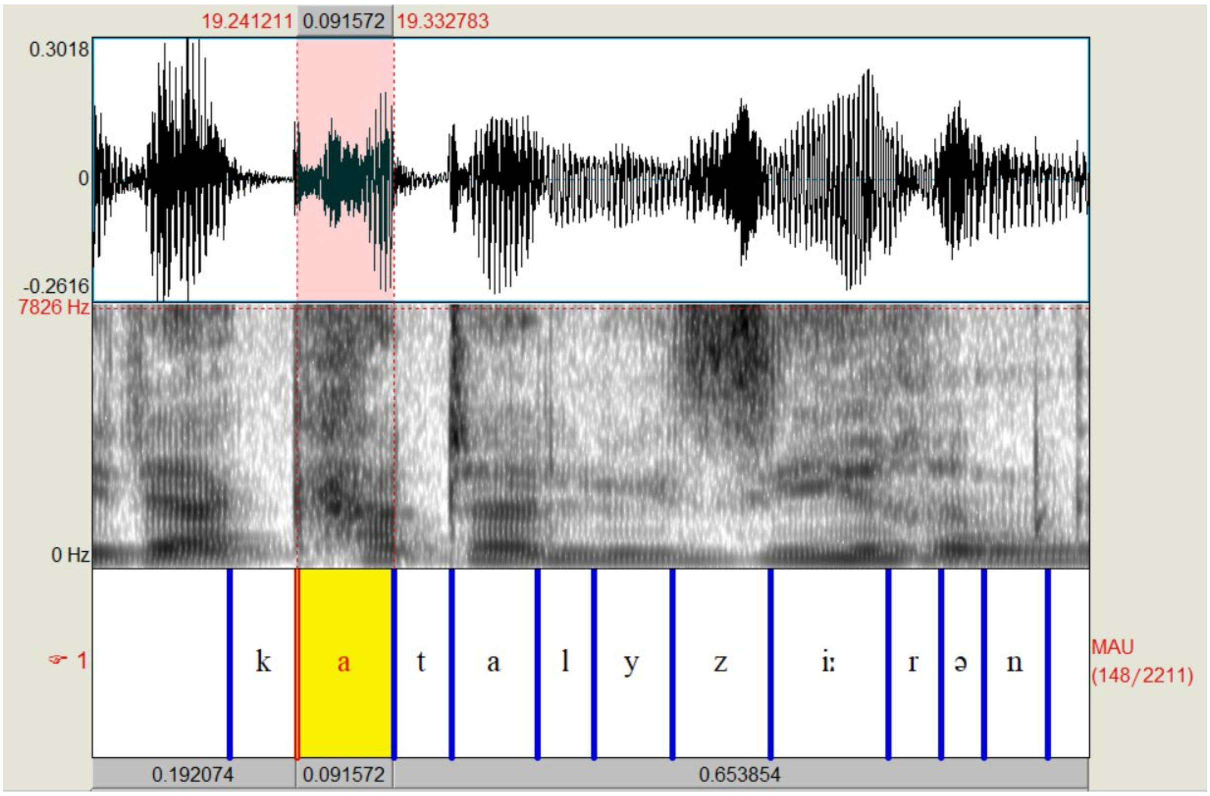


Figure (15). Segmentation of [ka] in *kàtalysíeren* as pronounced by female speaker D13.



A Praat script was used to extract the acoustic parameters mentioned in section (15.2.3) from each vowel of the target words. All instances of words that were mispronounced or pronounced with hesitation were deleted from the analysis. In the case of the items with secondary stress, most of the items were deemed to have a secondary stress on the initial syllable, although in many realizations the prominence of this type of secondary stress is very weak and not easily detectable.

The data were analyzed through mixed-effects regression analysis using the *lmer* package in *R* (R Core Team 2021). Two different sets of analyses were performed, one on the items aimed at analyzing primary stress and one on the items aimed at analyzing secondary stress. For each investigated acoustic parameter a model was built including the relevant acoustic parameter as dependent variable.

In the case of primary stress, the relevant acoustic parameter was included as dependent variable (e.g. *Duration*) and the following variables were included as predictors: *Stress*, referring to stressed or unstressed vowels, *Item*, referring to *Pápa* or *Pánama*, and then the variables *Sex*, *Age* and *Region*. The variable *ID*, referring to the single participants, was added as random effect. In order to analyze the possible effect of *Word_length* on *Stress* an interaction was created between these two variables, so that the maximum model, using *Duration* as dependent variable, looks like the one in (57):

(57) Duration ~ Stress*Word_length + Sex + Age + Region + (1|ID)

Model selection was performed using the stepwise variable selection procedure implemented in the *step()* function, which selects the best model based on AIC values. The *step()* function was thus applied to the model in (57), returning as output the best-fitting model. The best-fitting model was further analyzed through the *summary()* function.

In order to further investigate the research questions concerning the effect of polysyllabic shortening, pairwise comparison through the *emmeans* package in R was performed between the stressed vowels of *Pápa* and *Pánama* for those parameters in which the interaction between *Stress*Word_length* was found to improve the model.

In the case of secondary stress, the relevant acoustic parameter was included as dependent variable (e.g. *Duration*) and the following variables were included as predictors: *Sec_stress*, referring to the first or second vowel, i.e. to the first secondary stressed vowel or the second unstressed vowel. The second added predictor was *Interval*, referring to the two tested words, one with an inter-stress interval of one syllable, i.e. *Fànatísmus*, and one with an inter-stress interval of two syllables, i.e. *kàtalysíeren.* The other predictors were *Sex*, *Age* and *Region.* The variable *ID*, referring to the single participants, was added as random effect. In order to analyze the possible effect of *Interval* on *Sec_stress* an interaction was created between these two variables, so that the maximum model, using *Duration* as dependent variable, looks like the one in (58):

(58) Duration ~ Sec_stress*Interval + Sex + Age + Region + (1|ID)

Model selection was performed using the stepwise variable selection procedure implemented in the *step()* function, which selects the best model based on AIC values. The *step()* function was thus applied to the model in (58), returning as output the best-fitting model. The best fitting model was further analyzed through the *summary()* function.

In order to further investigate the research questions concerning whether secondary stressed is manifested more prominently in words with a higher inter-stress interval, pairwise comparison through the *emmeans* package in R was performed between the first secondary stressed vowel of *Fánatismus* and the first secondary stressed vowel of *kátalysieren* for those parameters in which the interaction between *Sec_stress*Interval* was found to improve the model.

15.3 Results

The following tables show the values of stressed and unstressed syllables for each of the investigated acoustic parameters. In the case of the tables referring to *Pápa* and *Pánama*, shaded cells of a row indicate that the insertion in the model of the variable *Stress*, which is the main predictor , significantly improves the model for that acoustic parameter ($p < 0.05$). In the case of the tables referring to *Fànatísmus* and *kàtalysíeren* , shaded cells of a row indicate that the insertion in the model of the variable *Sec_stress*, which is the main predictor, significantly improves the model for that acoustic parameter ($p < 0.05$). For each acoustic parameter, the highest value of that parameter is highlighted in bold.

In the tables reporting the results for items pooled together, the column labeled 'Significant variables', reports all the variables that were found to significantly improve the model for a particular acoustic parameter, i.e., *Sex*, *Age*, *Region*, *Word_length*, and *Interval*, including *Stress* and *Stress*Word_length* (only for primary stress) and *Sec_stress* and *Sec_stress*Interval* (only for secondary stress). The column labeled 'Pairwise comparisons: stressed vowels', reports the results of the comparison between the primary stressed vowels (in the case of *Pápa and Pánama*) or between the secondary stressed vowels (in the case of *Fànatísmus* and *kàtalysíeren*).

The results concerning primary stress are reported first in tables (50-54), followed by the results concerning secondary stress reported in tables (55-59).

With respect to primary stress, table (50) reports the results pooled from both items (*Pápa, Pánama*), while the subsequent tables (51-54) report the results for single items. Each table of results is followed by a descriptive table reporting the absolute values of each acoustic parameter for each vowel of the item.

With respect to secondary stress, table (55) reports the results pooled from both items (*Fànatísmus, kàtalysíeren*), while the subsequent tables (56-59) report the results for single items. Each table of results is followed by a descriptive table reporting the absolute values of each acoustic parameter for each vowel of the item.

In the tables, the following abbreviations are used: A = antepenult, P = penult, F = final, PS = primary stress, SS = secondary stress. The vowels in the words *Fànatísmus* and *kàtalysíeren* are numbered 1, 2, 3 etc. from the first vowel to the last.

Overall, in the case of the items aimed at analyzing primary stress, out of a total of 90 realizations for each item (3 repetitions by 30 speakers) some had to be discarded because of mistakes or hesitation in the pronunciation. The discarded realizations were: 19 for *Pápa* and 30 for *Pánama*. In the case of the items aimed at analyzing secondary stress, out of a total of 90 realizations for each item (3 repetitions by 30 speakers) some had to be discarded because of mistakes or hesitation in the pronunciation or because secondary stress was deemed to be either not clearly detectable or not on the first syllable. The discarded realizations were: 1 for *Fànatísmus* and 7 for *kàtalysíeren*.

15.3.1 Results for primary stress

Shaded rows indicate that the main predictor *Stress* (stressed vowels *vs* unstressed vowels) significantly improves the model. All significant predictors are also included in the last column of each table labeled 'Significant variables'.

Table (50). Results for *Pápa* and *Pánama* pooled together.

	Stressed vowel	**Unstressed vowel**	**Significant variables**	**Pairwise comparisons: stressed vowels**
Duration	**113**	95.1	Stress, Word_length, Stress*Word_length	Pánama > Pápa $p < 0.0001$
Intensity	66.3	**70.8**	Stress, Sex	
F0	**221**	170	Stress, Word_length,	

			Sex	
F1	**990**	784	Stress, Word_length, Sex	
F2	**1529**	1383	Stress, Sex	
Spectral tilt	**-0.00666**	-0.00828	Stress, Word_length, Stress*Word_length, Sex, Age	Pánama > Pápa p = 0.01

Table (51). Results for *Pápa.*

	Stressed vowel	**Unstressed vowels**	**Significant variables**
Duration	**105**	96.6	Stress
Intensity	66.6	**70.8**	Stress, Sex
F0	**228**	181	Stress, Sex
F1	**978**	747	Stress, Sex
F2	**1525**	1381	Stress, Sex
Spectral tilt	**-0.00686**	-0.00907	Stress

Table (52). Descriptive values of the vowels of *Pápa.*

	1	**2**
Duration	**105**	96.6
Intensity	66.6	**70.8**
F0	**228**	181
F1	**978**	747
F2	**1525**	1381
Spectral tilt	**-0.00686**	-0.00907

Table (53). Results for *Pánama.*

	Stressed vowel	**Unstressed vowel**	**Significant variables**
Duration	**122**	88.4	Stress
Intensity	66	**70.8**	Stress, Sex
F0	**213**	163	Stress, Sex
F1	**1004**	806	Stress, Sex
F2	**1533**	1384	Stress, Sex
Spectral tilt	**-0.00642**	-0.00780	Stress, Sex, Age

Table (54). Descriptive values of the vowels of *Pánama.*

	Vowels		
	1 (PS)	**2**	**3**

Duration	**122**	82.6	94.3
Intensity	66	**72.9**	68.6
F0	**213**	179	147
F1	**1004**	781	831
F2	**1533**	1393	1374
Spectral tilt	**-0.00642**	-0.00789	-0.00772

15.3.2 Results for secondary stress

Shaded rows indicate that the main predictor *Sec_stress* (1° vowel, i.e. secondary stressed vowel, vs 2° vowel, i.e. unstressed vowel) significantly improves the model. All significant predictors are also included in the last column of each table labeled 'Significant variables'.

Table (55). Results for *Fànatísmus* and *kàtalysíeren* pooled together.

	1° secondary stressed vowel	**2° unstressed vowel**	**Significant variables**	**Pairwise comparisons: secondary stressed vowels**
Duration	79.5	**81.1**	Sec_stress, Interval, Sec_stress *Interval	ka[128] > Fa, $p < 0.0001$
Intensity	68.8	**70.6**	Sec_stress, Interval, Sec_stress *Interval	Fa > ka, $p < 0.0001$
F0	**196**	186	Sec_stress, Interval, Sex, Region	ka > Fa, $p < 0.0001$
F1	**839**	647	Sec_stress, Interval, Sec_stress *Interval, Sex	ka > Fa, $p < 0.0001$
F2	1560	**1561**	Sec_stress, Interval, Sec_stress *Interval, Sex	ka > Fa, $p < 0.0001$
Spectral tilt	-0.00682	**-0.00484**	Sec_stress, Interval, Sec_stress *Interval	ka > Fa, $p < 0.0001$

Table (56). Results for *Fànatísmus.*

	1° secondary stress vowel	**2° unstressed vowel**	**Significant variables**
Duration	54.7	**71.8**	Sec_stress
Intensity	**73**	72.9	[none]
F0	**191**	179	Sec_stress, Sex
F1	**758**	739	Sex[129]

[128] *Ka* refers to the first vowel of *kàtalysíeren* and *Fa* to the first vowel of *Fànatísmus*.
[129] *Sec_stress* and *Region* were almost statistically significant, with $p = 0.072$ for *Sec_stress* and $p = 0.055$ for *Region*.

F1 (only females)	**793**	779	[none]
F2	1377	**1489**	Sec_stress, Sex
Spectral tilt	-0.00742	**-0.00587**	Sec_stress

Table (57). Descriptive values of the vowels of *Fànatísmus.*

Vowels	**1 (SS)**	**2**	**3 (PS)**	**4**
Duration	54.7	71.8	55.6	**76.9**
Intensity	**73**	72.9	71.1	68.8
F0	191	179	**224**	172
F1	**758**	739	438	491
F2	1377	1489	**1673**	1123
Spectral tilt	-0.00742	-0.00587	**-0.00456**	-0.00485

Table (58). Results for *kàtalysíeren.*

	1° secondary stress vowel	**2° unstressed vowel**	**Significant variables**
Duration	**104**	90.2	Sec_stress, Region
Intensity	64.8	**68.4**	Sec_stress
F0	**202**	194	Sec_stress, Sex, Age, Region
F1	**920**	556	Sec_stress, Sex
F2	**1740**	1634	Sec_stress, Sex
Spectral tilt	-0.00623	**-0.00381**	Sec_stress

Table (59). Descriptive values of the vowels of *kàtalysíeren.*

Vowels	**1 (SS)**	**2**	**3**	**4 (PS)**	**5**
Duration	104	90.2	77.0	**129**	50.7
Intensity	64.8	68.4	70.5	**71.8**	70.8
F0	202	194	183	**207**	172
F1	**920**	556	312	326	473
F2	1740	1634	2038	**2162**	1374
Spectral tilt	-0.00623	-0.00381	-0.00410	**-0.00275**	-0.00577

15.4 Discussion of results

15.4.1 Discussion of results: primary stress

15.4.1.1 Duration

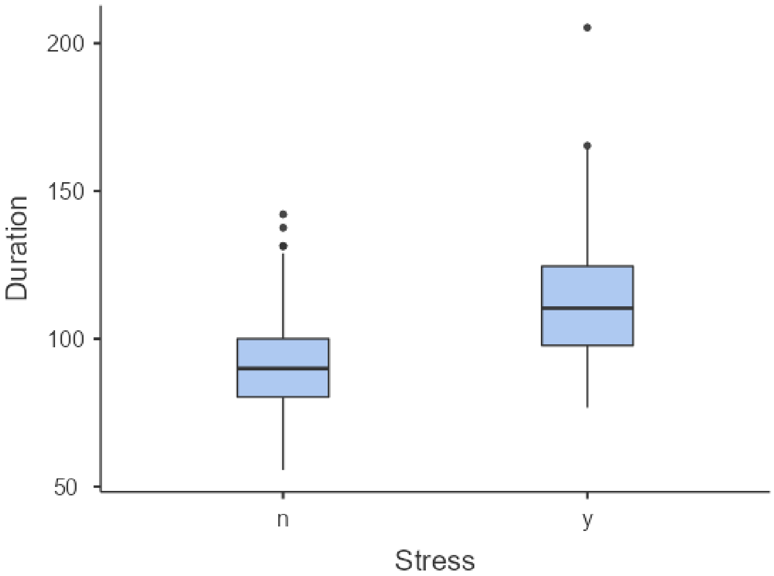
Looking at table (50) with the results for both *Pápa* and *Pánama* pooled together, it can be seen that the variable *Stress* significantly improves the model with respect to duration, as well as the interaction *Stress*Word_length*. Overall, stressed vowels are longer than unstressed vowels, in line with the expectations. Looking at the results for single items (tables 51 and 53), it can be seen that the significance of the variable *Stress* on duration is confirmed for both *Pápa* and *Pánama*. Overall, these results confirm duration as a reliable correlate of primary stress in German, as was found also in other studies. On a descriptive note, looking at the descriptive values for *Pánama* (table 54), it can be seen that on average duration is higher in the third unstressed vowel in comparison to the second unstressed vowel. Since this increase cannot be attributed to final lengthening (the target words were embedded in the carrier sentence *Sie hat schon wieder X gesagt*), it might perhaps be explained as due to the presence of a secondary stress.[130]

With respect to the research question related to polysyllabic shortening, i.e. whether vowels in words with more syllables are on average shorter than vowels in words with less syllables, looking at the results of the pairwise comparison between the stressed vowel of *Pápa* and the stressed vowel of *Pánama* in the last column of table (50), it can be seen that the stressed vowel of *Pánama* (122 ms) is on average longer than the stressed vowel of *Pápa* (105 ms) of 17 ms and the difference is also statistically significant.[131] These results thus suggest that polysyllabic shortening with respect to vowel duration does not play a role in these two types of words, i.e. between words of two and three syllables, in German. These results are in line with Siddins *et al.* (2014)'s results, who did not find any effect of polysyllabic shortening on the duration of the vowel [a] between words of one and two syllables in German.

Figure (16). Box plots of the duration values for the two items pooled together (*Pápa*, *Pánama*). On the x-axis: y = stressed vowels, n = unstressed vowels.

[130] One speaker consistently pronounced *Pánama* with stress on the final syllable, which caused for the vowel to lengthen, as a consequence the data of *Pánama* for this participant were taken out of the analysis. It might still be possible, however, that some other participants tended to lengthen the final vowel, perhaps influenced by the native Spanish pronunciation of *Panama* which has stress on the final syllable.

[131] One tentative explanation for this result might be that the longer duration of [a] in the stressed syllable of *Pánama* in comparison to *Pápa* might be due to the tendency for vowels to be longer before voiced consonants than before voiceless consonants (see Kluender *et al.* 1988 and the references therein).



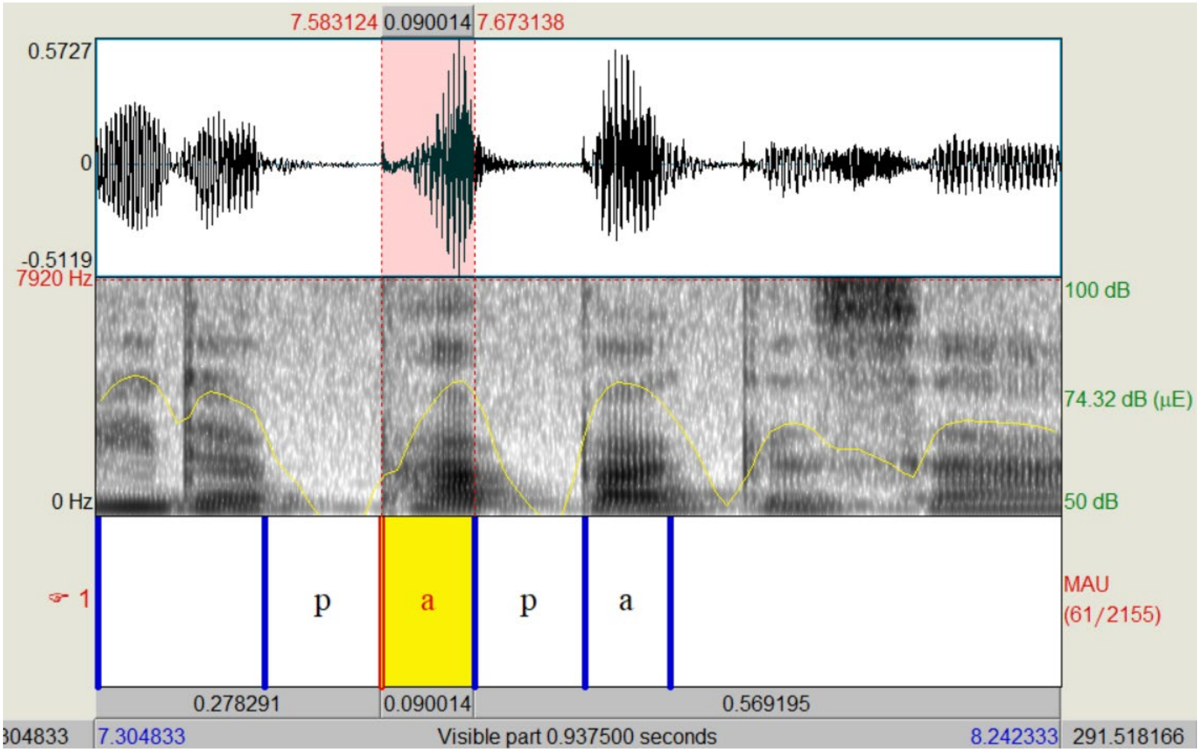
15.4.1.2 Intensity

Looking at table (50) with the results for both *Pápa* and *Pánama* pooled together, it can be seen that the variable *Stress* significantly improves the model with respect to intensity and the same is found also looking at the results for single items (tables 51, 53). Somewhat unexpectedly, *Sex* has also been found to improve the model, with male participants producing on average a higher intensity than female participants (estimate = 3.5579 dB).

However, looking at tables 51 and 53 for single items and their respective descriptive tables (52, 54), it can be seen that intensity is always higher in the unstressed vowels. In the case of *Pánama*, of all the three vowels, the stressed vowel is the one with the lowest intensity. Overall, these results seem to suggest that intensity cannot be considered a reliable correlate of primary stress in German.

However, looking at the spectrogram of the target words *Pápa* and *Pánama*, it can be seen that intensity is considerably higher on the part of the vowel comprised between the onset of voicing and the beginning of the following consonant in comparison to the part comprising the aspiration of the preceding stop consonant, which, as explained in 15.2.4 was segmented as part of the following vowel. This can be seen in figure (17), which contains an example taken from one instance of *Pápa*.

Figure (17). Intensity contour of the word *Pápa* pronounced by the female speaker D21.



With respect to the first vowel [a] in figure (17), it can be seen that, in the part of the vowel which contains the aspiration of the preceding [p], intensity is extremely low and for this reason, when averaged together with the intensity of the second part containing the voicing, the results will be that the average intensity of the first [a] of *Pápa* will be lower than the average intensity of the second [a]. On the contrary, if the aspiration of the previous [p] is excluded from the segmentation of the vowel [a], on average the intensity of the stressed vowel seems to become as high as that of the unstressed vowel, or slightly higher. However, excluding the aspiration of the previous stop consonant from the segmentation of the vowel seems also to result in a stressed vowel with a much shorter duration than the unstressed vowel. In order to test the hypothesis of whether the reliability of intensity and duration as correlates of stress is significantly influenced by the segmentation criteria, an alternative segmentation for the words *Pápa* and *Pánama* has been carried out, in which the aspiration of [p] is excluded from the segmentation of the following vowels. The results, averaged for both target words, indicate an intensity of the stressed [a] of 72.3 dB *vs* an intensity of 70.7 dB for the unstressed [a] and also a duration of the stressed [a] of 52.4 ms *vs* a duration of 99.1 ms for the unstressed [a], confirming the hypothesis formulated above. A new analysis using a mixed-effects model has been also carried out using this new data. The results suggest that *Stress* significantly improves the model with respect to the dependent variable *Intensity* ($p < .001$), suggesting that in the segmentation that excludes the aspiration from the vowel, intensity might be considered a reliable correlate of primary stress, with stressed vowels having higher intensity than unstressed vowels. With respect to *Duration* as dependent variable, the results of the statistical analysis indicate that *Stress* significantly improves the model ($p < .001$), suggesting that in the segmentation that excludes the aspiration from the vowel, duration cannot be considered a reliable correlate of primary stress anymore, since stressed vowels are significantly shorter than unstressed vowels. A perception experiment, comparing different levels of intensity and duration in these types of words, might perhaps shed some light concerning whether speakers use intensity of the 'restriced' version of the vowel [a] or duration of the 'expanded' version of vowel [a] as a more reliable correlate of stress.

Overall, these results suggest that segmentation criteria can play a crucial role in analyzing the acoustic correlates of stress. The reason why in the literature duration but not intensity is usually found to be a strong correlate of primary stress, might perhaps in part be due to the segmentation criteria used.[132] On a more general note, these ambivalent results related to segmentation and to the definition of the *locus* of stress also suggest that perhaps the *locus* of stress should not be considered exclusively to be the syllable nucleus, i.e. the vowel. On the contrary, although the syllable nucleus most likely plays the major role with respect to the acoustic correlates of stress, it might be the case that the nucleus also strongly interacts with the surrounding segments, as corroborated also by the fact that some studies found also the onset and the coda to be influenced by stress (e.g. Ortega-Llebaria 2006 with respect to onset, in Spanish). Therefore, considering the interaction between the nucleus and the surrounding segments might allow to develop a more fine-grained model for the acoustic correlates of stress.

15.4.1.3 F0

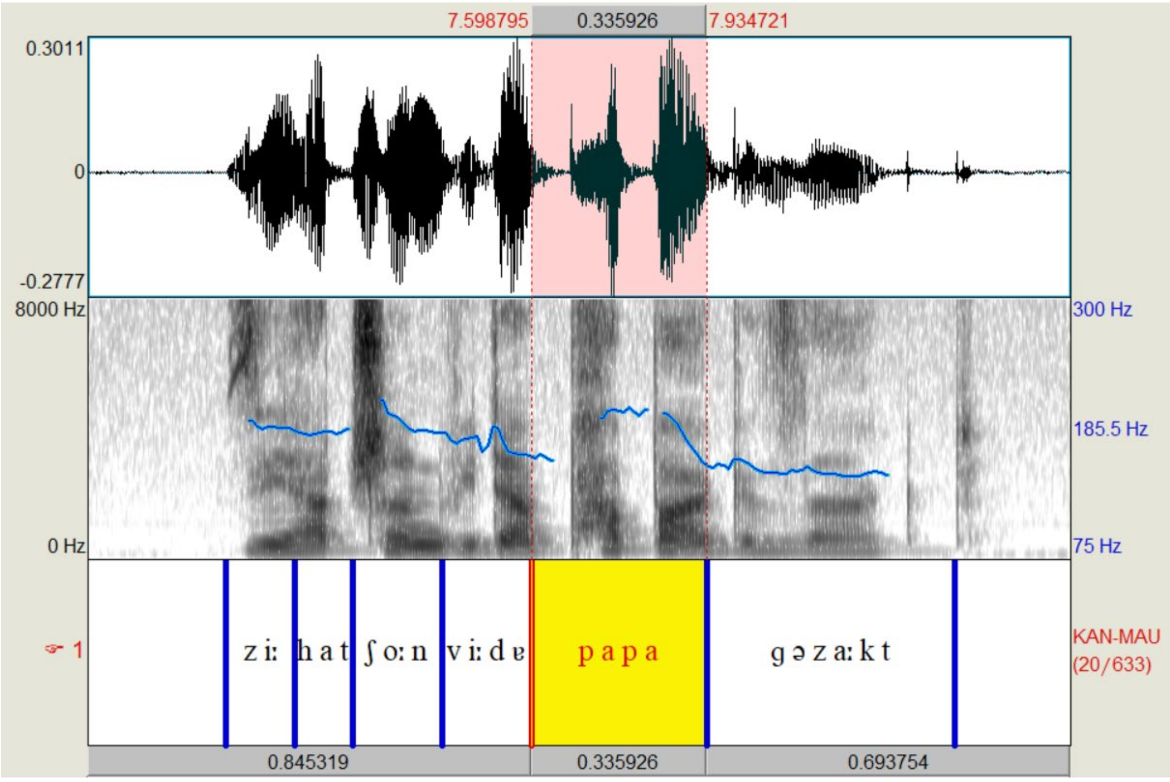
Looking at table (50) with the results for both *Pápa* and *Pánama* pooled together, it can be seen that the variable *Stress* significantly improves the model with respect to F0 and the same is found also looking at the results for single items (tables 51 and 53). Also looking at the descriptive tables for single items (52, 54), it can be seen that F0 is systematically higher on the first stressed vowel of each word and then gradually decreases towards the final vowel.

As expected, *Sex* has also been found to improve the model, with male participants producing on average a lower F0 than female participants (estimate = -81.742 Hz).

[132] It has to be noted, however, that the issue related to the segmentation of the aspiration described above concerns exclusively stop consonants at the beginning of a word.

Looking at the spectrograms of the target words, it has been noticed that F0 overall starts high at the beginning of the carrier sentence *Sie hat schon wieder X gesagt* 'She said X again', gradually decreases towards the target word, then rises on the stressed vowel of the target words, which is in accented position, and finally decreases again, as can be seen in the example in figure (18).

Figure (18). F0 contour of *Sie hat schon wieder Papa gesagt* pronounced by female speaker D13.



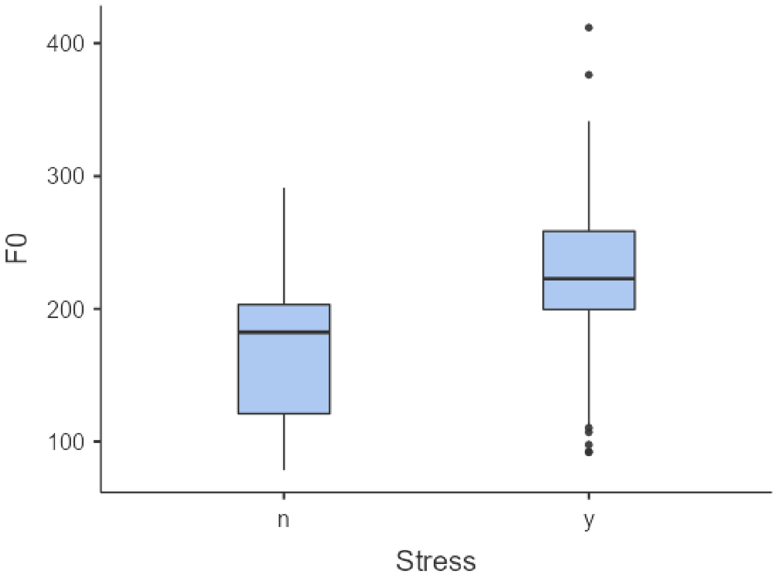
This downward pattern of F0 is in line with a declarative pattern, which is expected to be associated with the sentence *Sie hat schon wieder X gesagt.*[133] It seems therefore that the stressed vowel of the target word in accented position breaks the downward pattern by raising F0 in a statistically significant way. However, on the basis of these results alone, it cannot be concluded that, overall, F0 is directly a correlate of primary stress. Rather it can be concluded that the F0 contour of a declarative pattern anchors to the stressed vowel of a word in accented position. Otherwise stated, it could be claimed that F0 is a correlate of primary stress, but only in accented condition. In order to establish whether F0 can be overall considered a correlate of primary stress in German, the same results found here should also be replicated in a target word in unaccented condition.

[133] No final F0 raising associated with a list-reading pattern was found, as was instead the case for Italian (see chapter 14).

Furthermore, in order to further corroborate these results, a new analysis should also be performed comparing the F0 values of the primary stressed vowel of the target word with the F0 values of the final vowel of the preceding word of the carrier sentence, i.e. *wider*, in other to see whether the difference in F0 between the two vowels is statistically significant, thus indicating whether there is an actual rise of F0 in correspondence with the primary stressed vowel.

Since no significant interaction between *Stress* and *Word_length* was found, this suggests that the stressed vowel of *Pápa* does not significantly differ from the stressed vowel of *Pánama* with respect to F0.

Figure (19). Box plots of the F0 values for the two items pooled together (*Pápa*, *Pánama*). On the x-axis: y = stressed vowels, n = unstressed vowels.



15.4.1.4 F1

Looking at table (50) with the results for both *Pápa* and *Pánama* pooled together, it can be seen that the variable *Stress* significantly improves the model with respect to F1 and the same is found also looking at the results for single items (tables 51 and 53). The descriptive tables (52, 54) indicate that F1 is systematically higher in the stressed vowel in comparison to the unstressed vowel, indicating a lower [a] in stressed position.

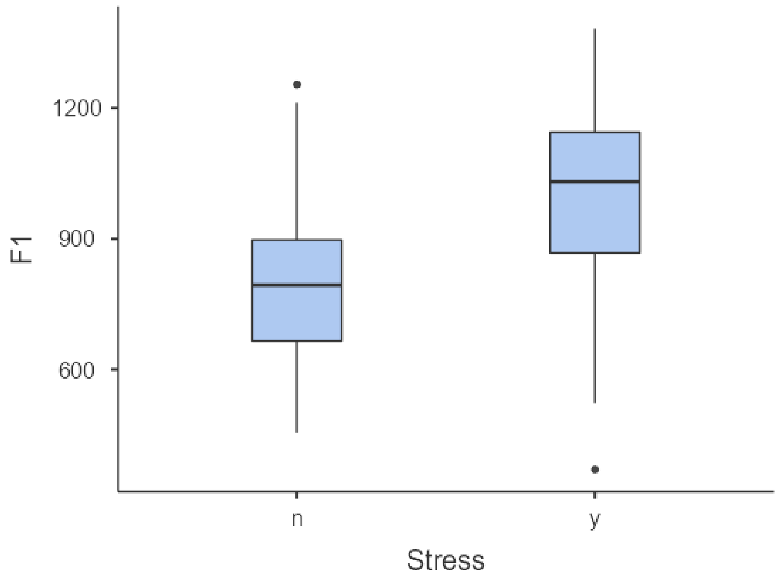
Overall, these results suggest that F1 can be considered as a reliable correlate of primary stress in German for the vowel [a], with stressed [a] having a significantly higher F1 than unstressed [a].

Furthermore, looking at the descriptive table for *Pánama* (table 52), it can be seen that the final unstressed vowel has a higher F1 than the penultimate unstressed vowel. The same pattern was found also for duration (see 15.4.1.1) and it might perhaps be interpreted as due to the presence of a secondary stress, which causes the final [a] to lower with respect to the preceding unstressed syllable.

As expected, *Sex* has also been found to improve the mode, with male participants producing on average a lower F1 than female participants (estimate = -246.89 Hz).

Since no significant interaction between *Stress* and *Word_length* was found, this suggests that the stressed vowel of *Pápa* does not significantly differ from the stressed vowel of *Pánama* with respect to F1.

Figure (20). Box plots of the F1 values for the two items pooled together (*Pápa*, *Pánama*). On the x-axis: y = stressed vowels, n = unstressed vowels.



15.4.1.5 F2

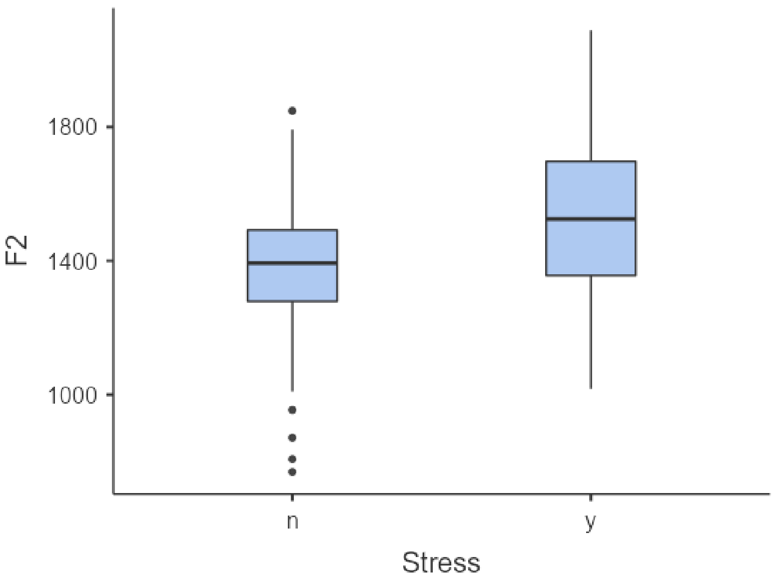
Looking at table (50) with the results for both *Pápa* and *Pánama* pooled together, it can be seen that the variable *Stress* significantly improves the model with respect to F2 and the same is found also looking at the results for single items (tables 51 and 53). The descriptive tables (52, 54) indicate that F2 is systematically higher in the stressed vowel in comparison to the unstressed vowel, indicating a more fronted [a] in stressed position. These data corroborate the results of Jessen's (1993), who found the same pattern, while they are different from the results of Dogil and Williams (1999) who found a lower F2 in stressed position in the vowel [a].

As expected, *Sex* has also been found to improve the mode, with male participants producing on average a lower F2 than female participants (estimate = -229.16 Hz).

Overall, the results of the present experiment suggest that F2 can be considered as a reliable correlate of primary stress in German for the vowel [a], with stressed [a] having a significantly higher F2 than unstressed [a].

Since no significant interaction between *Stress* and *Word_length* was found, this suggests that the stressed vowel of *Pápa* does not significantly differ from the stressed vowel of *Pánama* with respect to F2.

Figure (21). Box plots of the F2 values for the two items pooled together (*Pápa*, *Pánama*). On the x-axis: y = stressed vowels, n = unstressed vowels.



15.4.1.6 Spectral tilt

Looking at table (50) with the results for both *Pápa* and *Pánama* pooled together, it can be seen that the variable *Stress* significantly improves the model with respect to Spectral tilt and the same is found also looking at the results for single items (tables 51 and 53). Furthermore, in the results of both *Pápa* and *Pánama* the interaction *Stress**Word_length* also significantly improves the model. Looking at the descriptive tables for single items (52, 54) it can seen that spectral tilt is systematically higher (i.e. less negative) in the stressed vowel in comparison to the unstressed vowels. These results are in line with the expectations to find a less steep tilt in stressed vowels in comparison to unstressed vowels, indicating that in stressed vowels intensity decreases less as a function of frequency than it does in unstressed vowels. These results are not in line, however, with the results found for German by Aronov and Schweitzer (2016), who measured the same type of spectral tilt and found that stressed vowels had lower values of spectral tilt (i.e. a steeper tilt) in comparison to unstressed vowels and thus claimed that perhaps measurements of spectral tilt that involve lower frequency ranges might be more sensitive to stress distinctions in comparison to measurements the involve higher frequency ranges, like the one used here.[134]

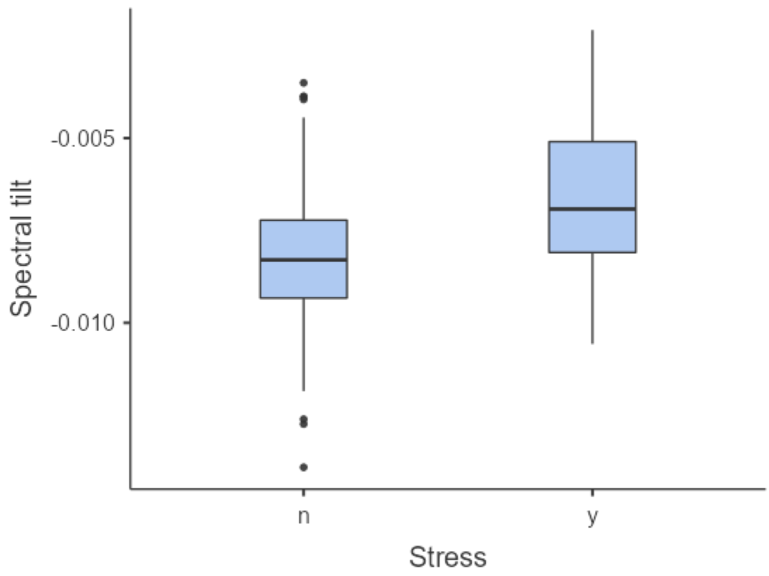
Overall, the results of the present experiment suggest that spectral tilt, measured as the regression line between intensity and frequency in a frequency spectrum of 1-5000 Hz, can be considered as a reliable correlate of primary stress in German, with stressed vowels having a higher (less negative) value of spectral tilt in comparison to unstressed vowels.

Furthermore, the interaction *Stress*Word_length* suggests that the difference between stressed and unstressed vowels with respect to spectral tilt varies significantly between *Pápa* and *Pánama*. The pairwise comparison between the stressed vowels of *Pápa* and *Pánama* indicates that the difference in spectral tilt between the two vowels is significant, with the stressed vowel of *Pánama* having a higher spectral tilt value (-0.00642) in comparison to the stressed vowel of *Pápa* (-0.00686). Since the stressed vowel in *Pánama* was also found to have a significantly higher duration than the stressed vowel in *Pápa,* the results for both duration and spectral tilt overall support the fact that stress, in terms of duration and spectral tilt, is manifested more prominently in the stressed vowel of *Pánama* than in the stressed vowel of *Pápa*. This is contrary to the expectations predicted by polysyllabic shortening, that would predict shorter vowels, and as a consequence, less prominent vowels in terms of spectral tilt, in *Pánama* with respect to *Pápa*.

Finally, somewhat unexpectedly, also *Sex* and *Age* have been found to significantly improve the model. With respect to *Sex*, the estimate of the fixed effect indicated that male speakers produced on average a value of spectral tilt which is -1.325e-03 lower than that of female speakers. With respect to *Age*, the estimate of the fixed effect indicated that spectral tilt decreases by -1.007e-04 for a one-unit increase in *Age*.

[134] The frequency range used here and in Aronov and Schweitzer (2016)'s study is: 1-5000 Hz. Aronov and Schweitzer (2016)'s claim was based on the fact that, besides measuring spectral tilt in the frequency range 1-5000 Hz, they also measured a second type of spectral tilt involving a lower frequency range, which, unlike the first type, was found to be in line with the expectations (see chapter 13).

Figure (22). Box plots of the spectral tilt values for the two items pooled together (*Pápa*, *Pánama*). On the x-axis: y = stressed vowels, n = unstressed vowels.



15.4.2 Discussion of results: secondary stress

15.4.2.1 Duration

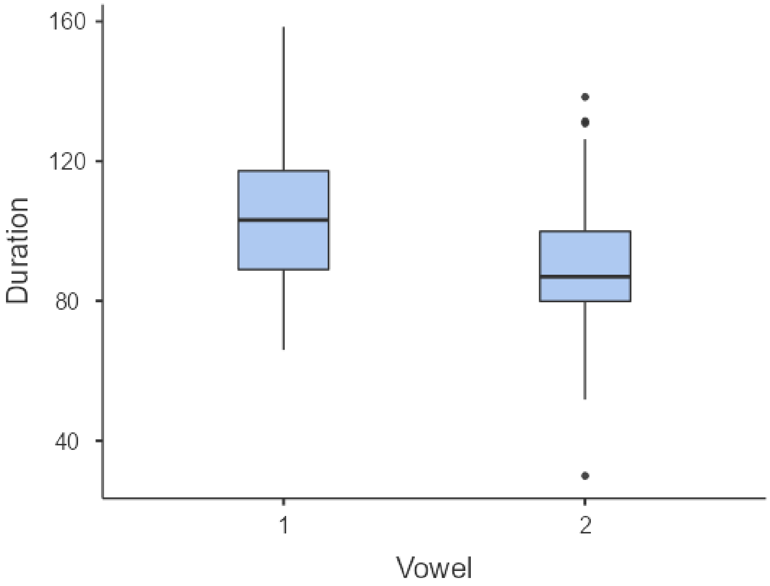
Looking at table (55) with the results for both *Fànatísmus* and *kàtalysíeren* pooled together, it can be seen that the variable *Sec_stress*, as well as the interaction *Sec_stress*Interval,* significantly improves the model with respect to duration. However, looking at the results for single items (tables 56 and 58), it can be seen that in *Fànatísmus* duration is lower in the first vowel, i.e. the one which is supposed to bear secondary stress, in comparison to the second unstressed vowel, while in *kàtalysíeren* the opposite pattern is found, i.e. the duration is higher in the first vowel in comparison to the second vowel. With respect to the other vowels in the two items, no particular patterns can be established due to the fact that all non-target vowels are different from [a], and as a consequence each has its own inherent duration that makes any comparison unreliable. On the basis of the fact that duration is higher in the first vowel in comparison to the second vowel only in *kàtalysíeren*, duration can be considered a correlate of secondary stress only in this item, although *Sec_stress* significantly improves both models for the single items.

However, it should be noted that the results for *kàtalysíeren* are strongly influenced by the segmentation criteria. As was the case for the items *Pápa* and *Pánama,* also in the case of *kàtalysíeren* the stop consonant [k] at the beginning of the word is characterized by aspiration, and, following the criteria in Turk *et al.* (2006) (see discussion in 15.2.4), the aspiration was segmented as part of the following vowel, thus increasing its duration. Looking at the alternative segmentation, i.e. a segmentation that does not include the aspiration as part of the vowel, the results for *kàtalysíeren* indicate an average duration for the first [a] of 47.5 ms and an average duration for the second [a] of 59.8, bringing the patterns in duration of the first two vowels similar to those of *Fànatísmus.*

On this basis, it cannot be straightforwardly concluded that the longer duration of the first vowel in *kàtalysíeren* should be considered a reliable correlate of secondary stress, because of its strong dependence on segmentation criteria. On the other hand, the data for *Pápa* and *Pánama,* with respect to primary stress, suggest that the segmentation that includes the aspiration as part of the vowel is more likely to reflect the way German speakers perceptually segment the vowel, since only this type of segmentation causes the primary stressed vowels to be longer than the unstressed vowels, which is in line with the data in all studies in the literature, according to which duration is a strong correlate of primary stress in German.

Under this view, we could tentatively claim that duration can be considered a correlate of secondary stress only in the case of *kàtalysíeren.* Furthermore, since the pairwise comparison between the first vowels of *Fànatísmus* and *kàtalysíeren* indicates that the difference in duration is significant ($p < 0.001$), these results support the hypothesis that secondary stress, with respect to duration, is manifested more prominently in words with a longer inter-stress interval in comparison to words with a shorter inter-stress interval, like *Fànatísmus,* although, in order to strengthen this conclusion, a replication study is needed, in which the data from two items with the same initial consonant are compared.

Figure (23). Box plots of the duration values for *kàtalysíeren*. On the x-axis: 1 = first secondary stressed vowels, 2 = second unstressed vowels.



15.4.2.2 Intensity

Looking at table (55) with the results for both *Fànatísmus* and *kàtalysíeren* pooled together, it can be seen that the variable *Sec_stress*, as well as the interaction *Sec_stress*Interval,* significantly improves the model with respect to intensity. However, intensity seems to be on average higher in the second vowel in comparison to the first vowel. Looking at the descriptive tables for single items (57, 59) however, it can be seen that intensity is higher in the first vowel in *Fànatísmus*, but it is lower in the first vowel in *kàtalysíeren.* Furthermore, looking at the results for the item *Fànatísmus* in table (56), it can be seen that neither *Sec_stress* nor any other of the investigated variables improved the model, so that intensity cannot be considered a reliable correlate of secondary stress in *Fànatísmus.* With respect to *kàtalysíeren*, in which intensity is higher in the second vowel in comparison to the first vowel, because of the ambiguity related to segmentation of the vowel [a] already discussed with respect to intensity and primary stress in section 14.4.1.2, it might be possible that excluding the aspiration from the segmentation of [a], intensity turns out to be higher in the first vowel. However, when excluding the aspiration from the segmentation of [a], the first vowel still results to have a lower intensity than the second vowel, with an intensity of 70.5 dB for the first vowel and an intensity of 71.3 for the second vowel.

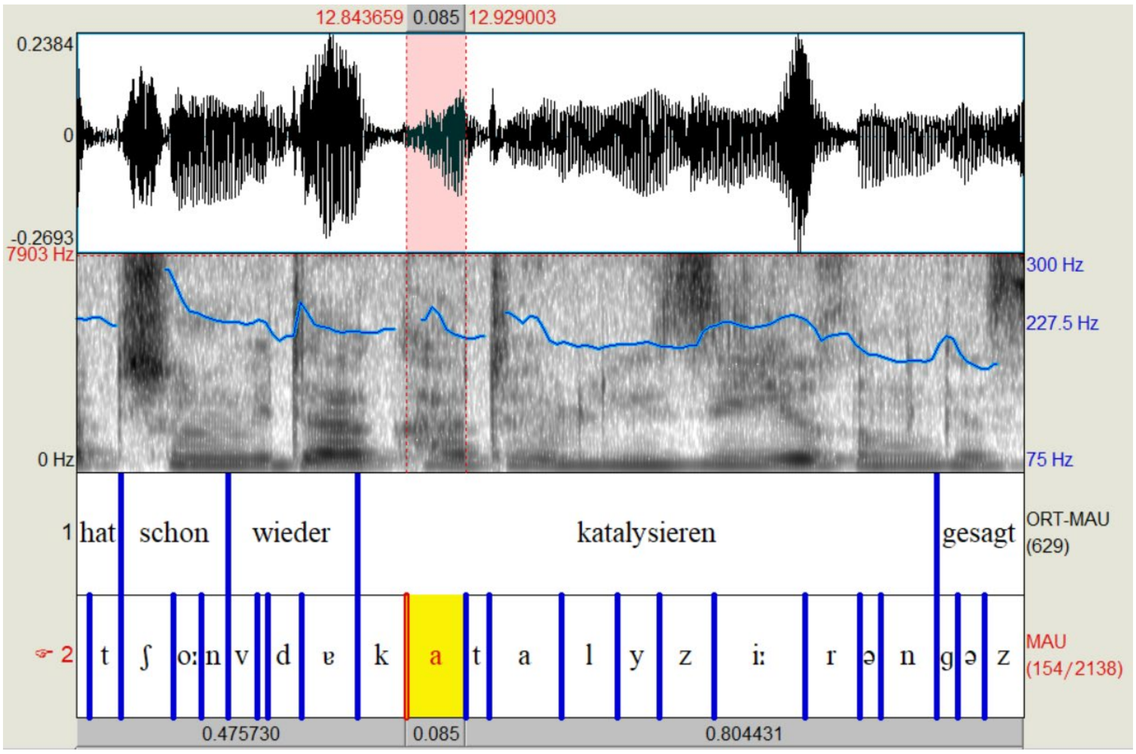
Overall, on the basis of these results, it can be thus concluded that intensity cannot be considered a reliable correlate of secondary stress in German.

15.4.2.3 F0

Looking at table (55) with the results for both *Fànatísmus* and *kàtalysíeren* pooled together, it can be seen that the variable *Sec_stress* significantly improves the model with respect to F0. As expected, also *Sex* improves the model, with male speakers having on average a lower F0 than female speakers (estimate = -112.498 Hz). The variable *Region* (referring to the state, i.e. the *Bundesland*, of origin of the participants) was also found to significantly improve the model. The differences in F0 that were found to be significant among the 8 regions represented in the study are: Bayern > Baden-Württemberg (est. = 29.235 Hz), Sachsen < Baden-Württemberg (est. = -56.046 Hz), Mecklenburg-Vorpommern < Bayern (est. = -53.515 Hz), Sachsen < Bayern (est. = -85.281 Hz), Sachsen < Hessen (est. = -59.111 Hz), Sachsen < Nordrhein-Westfalen (est. = -57.090 Hz), Sachsen < Sachsen-Anhalt (est. = -89.829 Hz) and Niedersachsen > Sachsen (est. 72.487 Hz). There was no state with a considerably higher number of males or females with respect to the other states, so these differences are unlikely to be due (exclusively) to a possible interaction between *Sex* and *Region*.

Turning back to the influence of the variable *Sec_stress*, it can be seen from the tables (56) and (58) that *Sec_stress* improves both models for single items. F0 is on average higher in the first vowel in comparison to the second vowel in both *Fànatísmus* and *kàtalysíeren.* Looking at the descriptive tables for single items (57, 59), it can be seen that F0 is systematically higher in the first vowel of each word, then gradually decreases and rises again in the primary stress vowel and finally decreases in the post tonic vowel. Looking at the spectrograms, it can be seen that, overall, F0 is higher at the beginning of the carrier sentence and tends to gradually decrease towards the end of the carrier sentence. However, as can be seen in the example in figure (24), F0 tends to rise in the primary stressed vowels in the sentence, including both the primary stressed vowel and the first vowel, i.e. the vowel which is supposed to bear a secondary stress, of the target word in focus position.

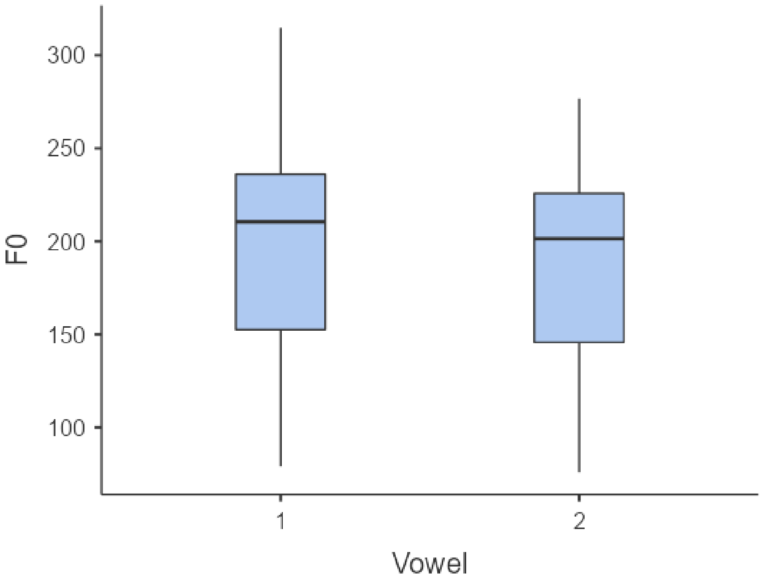
Figure (24). F0 contour of the sentence *Sie hat schon wieder katalysieren gesagt* pronounced by female speaker D25**.**



On the basis of these results, as was the case for primary stress, it is not possible to conclude that F0 is directly a correlate of secondary stress, however it can be concluded that the F0 contour anchors to a secondary stressed vowel (as it does to a primary stressed vowel), which causes an increase of F0 in the first secondary stress vowel which is statistically significant with respect to the second unstressed vowel. In order to establish whether F0 can be considered a correlate of secondary stress in all cases, the same results should also be replicated in a word in unaccented condition. Moreover, in order to further corroborate these results, a new analysis should also be performed, comparing the F0 values of the secondary stressed vowel of the tartget word with the F0 values of the final vowel of the preceding word of the carrier sentence, i.e. *wider*, in other to see whether the difference in F0 between the two vowels is statistically significant, thus indicating whether there is an actual rise of F0 in correspondence with the secondary stressed vowel.

Furthermore, the pairwise comparison between the secondary stressed vowel in *Fànatísmus* and the secondary stressed vowel in *kàtalysíeren* indicates that the difference is significant, with the the secondary stressed vowel in *kàtalysíeren* (202 Hz) having a higher F0 than the secondary stressed vowel in *Fànatísmus* (191 Hz). These results support the hypothesis that, with respect to F0, secondary stress is manifested more prominently in words with a longer inter-stress interval in comparison to words with a lower inter-stress interval.

Figure (25). Box plots of the F0 values for the two items pooled together (*Fànatísmus*, *kàtalysíeren*). On the x-axis: 1 = first secondary stressed vowels, 2 = second unstressed vowels.



15.4.2.4 F1

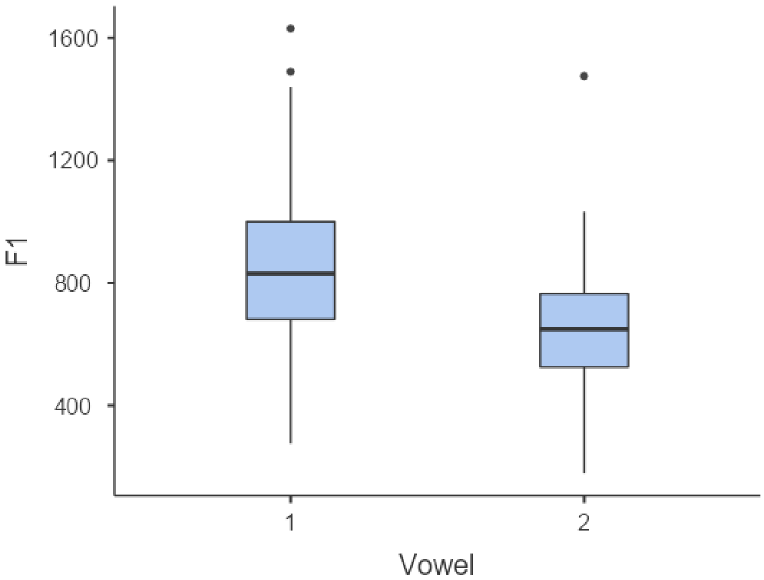
Looking at table (55) with the results for both *Fànatísmus* and *kàtalysíeren* pooled together, it can be seen that the variable *Sec_stress,* as well as the interaction *Sec_stress*Interval*, significantly improves the model with respect to F1. With respect to the models for single items in tables (56) and (58), it can be seen however that *Sec_stress* significantly improves the model in *kàtalysíeren* but not in *Fànatísmus*. In order to see whether the results for *Fànatísmus* were due to the variability in F1 related to male and female participants, a second analysis has been run with only the data from the female participants, reported in the row with the label 'F1 (only females'). However, also in this new analysis *Sec_stress* did not improve the model with respect to F1 for the item *Fànatísmus*. However, in the case of *Fànatísmus,* in the analysis with both male and female participants the p-values for *Sec_stress* almost reach statistical significance (p = 0.07).

The descriptive results indicate that F1 is systematically higher in the first vowel in comparison to the second vowel in both *Fànatísmus* and *kàtalysíeren*, indicating that the first [a] is significantly lower/more peripheral than the second [a]. As expected, also *Sex* turns out to improve the model, with male speakers producing a lower F1 in comparison to female speakers (estimate = -144.88 Hz). With respect to the F1 values of other vowels besides the first two in *Fànatísmus* and *kàtalysíeren* no pattern can be established, since these vowels have different qualities and as a consequence different inherent formant values. In the case of the model for *Fànatísmus*, one possibility is that the halving of the data might have reduced the statistical significance of the difference between the first two vowels.

Overall, these results seem to suggest that F1 can be considered a reliable correlate of secondary stress in German for the vowel [a], with a vowel [a] in secondary stressed position having a significantly higher value of F1 in comparison to a vowel in unstressed position.

With respect to the differences between items, from the pairwise comparison in table (55), it can be seen that on average the secondary stressed vowel of *kàtalysíeren* has a significantly higher F1 in comparison to the secondary stressed vowel of *Fànatísmus* (920 *vs* 758 Hz, respectively). These results support the hypothesis that secondary stress with respect to F1 is manifested more prominently in words with a longer inter-stress interval in comparison to words with a shorter inter-stress interval, which might also further explain why the p-value for the variable *Sec_stress* is highly significant for *kàtalysíeren* ($p < 0.001$) but only almost significant for *Fànatísmus* ($p = 0.07$).

Figure (26). Box plots of the F1 values for the two items pooled together (*Fànatísmus*, *kàtalysíeren*). On the x-axis: 1 = first secondary stressed vowels, 2 = second unstressed vowels.

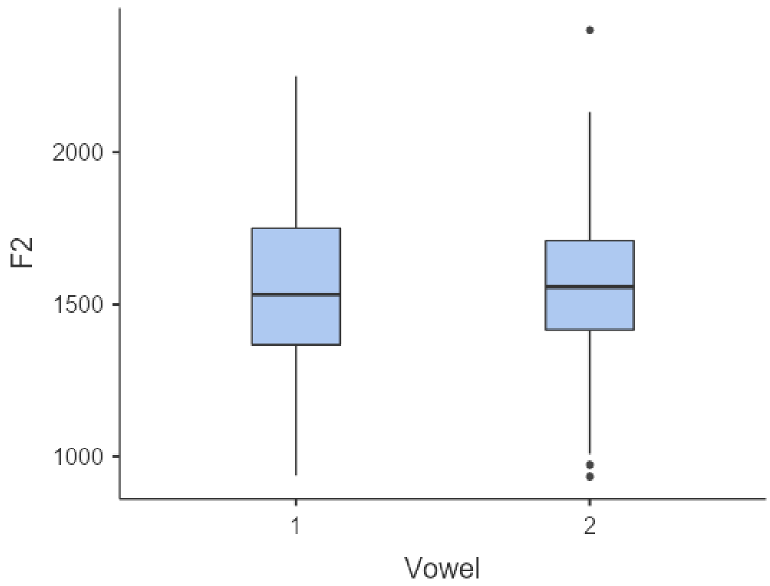


15.4.2.5 F2

Looking at table (55) with the results for both *Fànatísmus* and *kàtalysíeren* pooled together, it can be seen that the variable *Sec_stress,* as well as the interaction *Sec_stress*Interval*, significantly improves the model with respect to F2, however F2 is found to be slightly higher in the second vowel in comparison to the first vowel, which is contrary to the expectations. As can be seen from tables (56) and (58) *Sec_stress* also improves both models for single items. However, F2 is found to be higher in the first vowel with respect to the second vowel only in *kàtalysíeren,* while in *Fànatísmus* F2 is higher in the second vowel. Since the expectations were to find a higher F2 in the secondary stressed vowel in comparison to the following unstressed vowel (as confirmed also from the results concerning primary stress, in which primary stressed vowels are found to have higher F2 than unstressed vowels), F2 could be considered a reliable correlate of secondary stress only for *kàtalysíeren* but not for *Fànatísmus.*

Looking at the pairwise comparison between the first vowel of *kàtalysíeren* and the first vowel of *Fànatísmus,* it can be seen that the first vowel of *kàtalysíeren* has significantly higher F2 than the first vowel of *Fànatísmus.* These results might support the hypothesis that secondary stress with respect to F2 is manifested more prominently in words with a longer inter-stress interval in comparison to words with a shorter inter-stress interval, although these conclusions are more tentative than in the case of F1, since, in the first vowel of *Fànatísmus,* F2 did not turn out to be a clear correlate of secondary stress.

Figure (27). Box plots of the F2 values for the two items pooled together (*Fànatísmus*, *kàtalysíeren*). On the x-axis: 1 = first secondary stressed vowels, 2 = second unstressed vowels.



15.4.2.6 Spectral tilt

Looking at table (55) with the results for both *Fànatísmus* and *kàtalysíeren* pooled together, it can be seen that the variable *Sec_stress,* as well as the interaction *Sec_stress*Interval*, significantly improves the model with respect to spectral tilt. Looking at the results for single items (tables 56 and 58), it can be seen that *Sec_stress* significantly improves also both models for *Fànatísmus* and *kàtalysíeren.* However, the results indicate that spectral tilt is systematically higher (closer to 0) in the second vowel in comparison to the first vowel, which is contrary to the expectations, which were to find a higher value of spectral tilt in the first vowel in comparison to the second vowel, indicating that the first secondary stressed vowel has a less steep tilt. On a purely descriptive note, it can be seen from tables (57) and (59) that spectral tilt has always the highest value in the primary stressed vowel, which is in line with the results obtained for *Pápa* and *Pánama*, in which spectral tilt was found to be a reliable correlate of primary stress, being higher in the stressed vowel.

Overall, spectral tilt cannot thus be considered a reliable correlate of secondary stress in German.

15.5 Conclusions

With respect to primary stress, the overall results indicate that duration can be considered a reliable correlate of primary stress, with stressed vowels significantly longer than unstressed vowels, in accordance with the results of most studies on primary stress in German. However, the results of the present study also suggest that the reliability of duration as a correlate of stress in German strongly depends on segmentation criteria, at least with respect to stop consonants at the beginning of a word, so that a replication of the same experiment without stop consonants might yield clearer insights. The results of this study also indicate no effect of polysyllabic shortening with respect to duration, with the stressed vowel in *Pánama* being longer than the stressed vowel in *Pápa*.

Intensity was not found to be a reliable correlate of primary stress, being on average higher in the unstressed vowels in comparison to stressed vowels. As was the case for duration, intensity was found to be highly dependent on the segmentation criteria of the word-initial stop consonant, since reversing the segmentation criteria causes intensity to become significantly higher in the stressed vowels in comparison to the unstressed vowel.

F0 was found to be a reliable correlate of primary stress in accented condition, with stressed vowels having a higher F0 than unstressed vowels. More specifically, the downward F0 contour of the carrier sentence *Sie hat schon wieder X gesagt* was found to anchor to the stressed vowels of the target word, which was always in accented condition. These results cannot however be generalized to target words in unaccented condition. No effect of polysyllabic shortening was found with respect to F0.

F1 was found to be a reliable correlate of primary stress, with stressed vowels having a higher F1 in comparison to unstressed vowels, indicating that vowels in stressed position are lower/more peripheral in comparison to vowels in unstressed position. No effect of polysyllabic shortening was found with respect to F1.

F2 was found to be a reliable correlate of primary stress, with stressed vowels having a higher F2 in comparison to unstressed vowels, indicating that vowels in stressed position are more fronted/more peripheral in comparison to vowels in unstressed position. These results are in line with the results in Jessen (1993) in which stressed [a] had higher F2 than unstressed [a] but they are not in line with the results in Dogil and Williams (1999), in which the opposite was found. No effect of polysyllabic shortening was found with respect to F2.

Spectral tilt was found to be a reliable correlate of primary stress, with stressed vowels having a higher spectral tilt (i.e. less negative, closer to 0) in comparison to unstressed vowels, indicating that vowels in stressed position have a less steep tilt than vowels in unstressed position, meaning that intensity at higher frequency decreases less in stressed vowels than it does in unstressed vowels. With respect to polysyllabic shortening, as in the case of duration, results contrary to the expectations were found, indicating no effect of polysyllabic shortening.

With respect to secondary stress, duration was found to be a possible correlate only in the case of *kàtalysíeren*, in which the first vowel, i.e. the vowel which is supposed to bear a secondary stress, was found to be significantly longer than the second vowel. In the case of *Fànatísmus*, the first vowel was found to be shorter than the second vowel. However, in the case of *kàtalysíeren*, as was the case for *Pápa* and *Pánama*, the duration of the first vowel was found to be strongly influenced by the segmentation criteria of the preceding stop consonant, since reversing the segmentation criteria causes the first vowel of *kàtalysíeren* to become shorter than the second vowel. With respect to possible differences related to the inter-stress interval, these results for duration seem to suggest that the secondary stressed vowel in *kàtalysíeren* is manifested more prominently than the secondary stressed vowel in *Fànatísmus*, although these conclusions cannot be considered definitive since secondary stress in terms of duration on the first vowel of *Fànatísmus* could not be clearly detected.

Intensity, as was the case for primary stress, was not found to be a reliable correlate of secondary stress, not even if the segmentation criteria are changed. Intensity was found to be higher in the first vowel with respect to the second vowel only in *Fànatísmus*, but the difference between the two vowels was not found to be significant.

F0, as was the case for primary stress, was found to be a reliable correlate of secondary stress in accented condition, with the secondary stressed vowel having a higher F0 than the following unstressed vowel. More specifically, the downward F0 contour of the carrier sentence *Sie hat schon wieder X gesagt* was found to anchor to the secondary stressed vowel of the target word, which was always in accented condition. These results cannot however be generalized to target words in unaccented condition. With respect to possible differences related to the inter-stress interval, the results indicate that the secondary stressed vowel in *kàtalysíeren* has a significantly higher F0 in comparison to the secondary stressed vowel in *Fànatísmus*, supporting the hypothesis that, with respect to F0, secondary stress is manifested more prominently in words with a longer inter-stress interval in comparison to words with a lower inter-stress interval.

F1, as was the case for primary stress, was found to be a reliable correlate of secondary stress, with the secondary stressed vowel having a higher F1 than the following unstressed vowel, indicating that the secondary stressed vowel is articulated lower/more peripheral in comparison to the following unstressed vowel. With respect to possible differences related to the inter-stress interval, the results indicate that the secondary stressed vowel in *kàtalysíeren* has a significantly higher F1 in comparison to the secondary stressed vowel in *Fànatísmus*, supporting the hypothesis that, with respect to F1, secondary stress is manifested more prominently in words with a longer inter-stress interval.

F2, as was the case for primary stress, was found to be a reliable correlate of secondary stress, with the secondary stressed vowel having a higher F2 than the following unstressed vowel, indicating that the secondary stressed vowel is articulated more fronted/more peripheral in comparison to the following unstressed vowel. However, these results for F2 are less conclusive than those for F1, since in the case of *Fànatísmus* the difference between the two vowels was not found to be significant by a very slight margin ($p = 0.07$). With respect to possible differences related to the inter-stress interval, the results indicate that the secondary stressed vowel in *kàtalysíeren* has a significantly higher F2 in comparison to the secondary stressed vowel in *Fànatísmus*, supporting the hypothesis that, with respect to F2, secondary stress is manifested more prominently in words with a longer inter-stress interval.

Spectral tilt, unlike in the case of primary stress, was not found to be a correlate of secondary stress, with the secondary stressed vowel having a lower spectral tilt than the following unstressed vowel, indicating a steeper tilt in secondary stress vowels, which is contrary to expectations.

Overall, duration, F0 (only in accented condition), F1 and F2 were found, to different degrees, to be reliable correlates of both primary and secondary stress in German, while spectral tilt was found to be a reliable correlate only of primary stress. Intensity, on the contrary, was not found to be a reliable correlate neither of primary nor secondary stress. Polysyllabic shortening was not found to play a role in the case of the difference between *Pápa* and *Pánama*, while with respect to the influence of the inter-stress interval on secondary stress in *Fànatísmus* and *kàtalysíeren*, an aspect that to my knowledge had not been investigated in German so far, it was found that secondary stress is manifested more prominently in words with the longer inter-stress interval in the case of all the parameters that were found to be correlates of secondary stress, i.e. duration, F0 (only in accented condition), F1 and F2.

16 Conclusions

The aim of this thesis was, on the one hand, to analyze how primary and secondary stress assignment works in Italian and German, especially with respect to the influence of syllable weight; on the other hand, to analyze how primary and secondary stress in Italian and German are realized from an acoustic point of view.

In order to analyze primary and secondary stress assignment and the influence of syllable weight, for each of the two languages a nonce word experiment and a corpus analysis have been carried out, while the acoustic correlates of primary and secondary stress have been investigated through a production experiment in which speakers were recorded while reading aloud real words.

With respect to primary and secondary stress assignment and the influence of syllable weight in Italian, the results of the nonce word experiment confirmed that primary stress has a default position on the penultimate syllable. The results also indicate that the weight of the penultimate syllable plays the major role with respect to stress assignment, since a heavy penult with either a consonant in the coda, a diphthong (either rising or falling) or the highly sonorous vowel /a/ attracts stress categorically. A penultimate syllable with a double onset also seems to attract stress but to a much lower degree than the other types of heavy syllables. On the contrary, a heavy antepenultimate syllable was not found to attract stress.

Concerning the possible effect of full parsing in 4-syllable words, the results indicated an effect of full parsing in LLLL nonce words, since in LLLL stress tends to fall on the penultimate syllable more frequently than in LLL, allowing the formation of two disyllabic trochees, as in (L̀L)(ĹL). The effect of parsing does not emerge when comparing LLHL to LHL, since stress already falls most frequently on the penultimate syllable in both types of nonce words because the heavy penult attracts stress categorically. In the case of LHLL *vs* HLL the effect of parsing seems to emerge only in the data of those speakers who show a higher-than-average tendency to place stress on the antepenultimate syllable in 3-syllable words.

With respect to secondary stress, the results confirm a directionality of secondary stress from left to right, indicating a default position of secondary stress on the first syllable and they also indicate that a second heavy syllable with either a consonant in the coda, a falling diphthong or, possibly, a rising diphthong attracts stress, suggesting that both primary and secondary stress are sensitive to syllable weight in a similar way.

The results of the corpus analysis on Italian mostly confirm the results of the nonce word experiment, since in all conditions the most frequently stressed syllable is the same in both the nonce word experiment and the corpus analysis. Furthermore, with respect to the influence of syllable weight, the same types of heavy syllables in penultimate position have been found to attract stress categorically in both analyses. In some conditions that do not have a penultimate heavy syllable, the percentage of stress on the penult varies significantly between the two analyses, perhaps due to the influence of morphology, which is present in the corpus but not in the nonce word experiment.

With respect to primary and secondary stress assignment and the influence of syllable weight in German, the results of the nonce word experiment confirm the default position of primary stress on the penultimate syllable. In accordance with previous studies, the results also confirm that the weight of the final syllable plays the major role with respect to stress assignment. More specifically, the results indicate that a final heavy syllable with a consonant in the coda or with a long vowel attracts stress and a final heavy syllable with two consonants in the coda or a diphthong attracts stress even more, suggesting that a final heavy syllable with two consonants in the coda or a diphthong counts as superheavy in German. The results thus suggest that, with respect to syllable weight, German possesses a three-way contrast in final position of the type CVCC, CVG > CVC, CVV > CV. A final heavy syllable with a double onset also seems to attract stress, although to a much lower degree than the above mentioned heavy syllables. With respect to the influence of a heavy penultimate syllable, the results suggest that a heavy penult with a consonant in the coda in LHL nonce words attracts stress, although the effect is very weak, since in nonce words with a final light syllable stress already tends to fall mostly on the penult irrespective of the structure of the other syllables. In addition, a penultimate heavy syllable with a long vowel in LHH attracts stress and a penultimate heavy syllable with a diphthong in LHH attracts stress more often than a penultimate heavy syllable with a long vowel. Overall, the results suggest that also the weight of the penultimate syllable plays a role in German, although it seems to emerge clearly only in words in which also the final syllable is heavy. With respect to the antepenultimate syllable, the results suggest that a heavy antepenult does not attract stress in HLL nonce words, confirming that if the final syllable is light, stress tends to fall on the penultimate syllable, as was also found in previous studies.

In the case of 2-syllable words, the results indicate that stress falls predominantly on the penultimate syllable in LL, HL and LH nonce words, suggesting a tendency to achieve full parsing into a disyllabic foot. However, in LH stress falls on the final more often than in the other two conditions, indicating that a final heavy syllable still attracts stress, although the influence of the heavy final seems to be overridden by the tendency to achieve full parsing in the majority of cases.

In the case of 4-syllable words, the results mirror those found in the case of 3-syllable words, i.e., in final position, a syllable with two consonants in the coda and a syllable with a diphthong count as superheavy, while a syllable with a consonant in the coda count as heavy (a syllable with a long vowel was not tested in this type of words). With respect to the influence of the penultimate syllable, the results of the 4-syllable words also confirm the influence of a syllable with a consonant in the coda or with a diphthong. The 4-syllable words also show an effect of full parsing, but only in those conditions with a final heavy syllable (LLLH).

With respect to secondary stress, the results confirm that secondary stress in German has a directionality from left to right, i.e. the default position of secondary stress is on the first syllable. The results also confirm that a second heavy syllable with a consonant in the coda attracts stress and that a second heavy syllable with a diphthong attracts stress more than a heavy syllable with a consonant in the coda, thus counting as superheavy (CVCC and CVV syllables were not tested with respect to secondary stress assignment). Overall, the results suggest that the three-way contrast of syllable weight found for primary stress is also present in the case of secondary stress.

The results of the corpus analysis on German also confirm the results of the nonce word experiment. Namely, as was the case in the nonce words, also in the lexicon the same three-way contrast of syllable weight in final position can be observed. However, the influence of a final heavy syllable on stress assignment in the lexicon can be clearly seen only when suffixed words are taken out of the analysis, suggesting that also morphology plays a role in stress assignment, possibly overriding the stress-assigning algorithm based on syllable weight.

The results of the corpus analysis also confirm the tendency for stress to fall on the penult in 2-syllable words and the tendency to achieve full parsing in LLLH words.

Overall, these results suggest that in both Italian and German syllable weight plays a clear role with respect to both primary and secondary stress assignment and that in both languages the same types of heavy syllables that attract primary stress also attract secondary stress. Further research might be dedicated to expanding the typology of possible heavy syllables in these two languages by investigating the influence of other syllable structures in different positions.

The second part of the thesis was aimed at analyzing the acoustic correlates of primary and secondary stress in Italian and German. This part was also aimed at analyzing whether the acoustic correlates of primary stress vary with respect to stress position in Italian and whether the acoustic correlates of primary stress interact with polysyllabic shortening in German. In both Italian and German, it was also investigated whether the acoustic correlates of secondary stress are realized more prominently in words with a higher inter-stress interval.

With respect to the acoustic correlates of primary stress in Italian, the results indicated that both duration and the first formant (F1) can be considered reliable correlates of primary stress, with stressed vowels /a/ being longer and having a lower F1 in comparison to unstressed vowels. The results also confirmed that duration of a stressed vowel varies with respect to the position of the vowel within the word, with a stressed vowel being longer in penultimate position in comparison to a stressed vowel in antepenultimate position, which is in turn longer than a stressed vowel in final position. The results further suggest that in a word in accented condition at the end of a sentence with a declarative prosodic pattern, the primary stressed vowel is associated with a lower F0 in comparison to the unstressed vowels, suggesting perhaps that the downwards F0 contour of a declarative sentence anchors to the primary stressed vowel of the word at the end of the sentence.

With respect to the acoustic correlates of secondary stress in Italian, the results suggest that, in a word in accented condition at the end of a sentence with a downwards declarative pattern, a secondary stressed vowel in the first syllable of the target word might cause an increase in F0, followed by a decrease in the following unstressed vowel. However, in order to establish whether the increase in F0 is significant, further research is needed also comparing the secondary stressed vowel of the target words with the vowels of the preceding words in the carrier sentence. In the case of F0, no effect of the inter-stress interval was found. Since most of the participants in the experiment on the acoustic correlates of stress in Italian come from northern Italy, these results can be considered valid especially for the variety of Italian spoken in the North of Italy but not necessarily for other varieties of Italian.

With respect to the acoustic correlates of primary stress in German, the results indicate that duration, F1 and F2 can all be considered reliable acoustic correlates of both primary and secondary stress, with both primary and secondary stressed vowels being longer than unstressed vowels and having higher F1 and F2 values than unstressed vowels. F0 was also found to increase in both the primary and secondary stressed vowels in comparison to the unstressed vowels, suggesting that the F0 contour anchors to both primary and secondary stress vowels. However, as in the case of Italian, the results concerning F0 can be considered valid only for words in accented condition and they should also be further corroborated by comparing the F0 values of primary and secondary stress of the target words with the vowels of the preceding words in the carrier sentence. Spectral tilt was found to be a reliable correlate of primary stress but not of secondary stress, with primary stressed vowels having a lower spectral tilt in comparison to unstressed vowels.

No effect of polysyllabic shortening was found with respect to the items aimed at analyzing the acoustic correlates of primary stress. However, an effect of the inter-stress interval was found in the case of all the parameters that were found to be correlates of secondary stress, i.e. duration, F1 and F2 and F0, with all of these parameters having higher values on the secondary stressed vowel of *kàtalysíeren* in comparison with the secondary stressed vowel of *Fànatísmus,* suggesting that secondary stress in German is realized more prominently in words with a longer inter-stress interval.

Overall, the results suggest that, in the case of German, both primary and secondary stress are realized similarly in terms of acoustic correlates. In the case of Italian, the acoustic correlates of secondary stress have been proved to be more difficult to detect. Perhaps, analyzing different types of measurements (e.g. duration at the level of the syllable or different measurements of spectral tilt) or analyzing different types of secondary stress, e.g. secondary stress in compounds, might yield more clear results with respect to the acoustic correlates of secondary stress in Italian.

When comparing the results concerning the Italian and German stress systems, it is possible to see that both stress systems share many commonalities but also some crucial differences.

With respect to stress placement and the influence of syllable weight, in both Italian and German primary stress is restricted to the last three syllables and the results provided in this work confirm that the default position of primary stress is on the penultimate syllable in both languages. However, Italian and German differ extensively concerning the types of syllables that count as heavy and how syllable weight influences stress assignment. Although in both languages syllable weight plays a clear role, in the case of Italian it is only the weight of the penultimate syllable that has been found to play a role in stress assignment, while in German it is the weight of the final syllable that plays the major role, and only to a lesser extent the weight of the penult. This distinction is partly due to the fact that in Italian the influence of the final syllable has not been investigated so far, since the phonological word in Italian tends not to end in a consonant, with the result that the final syllable is often (although not always) of the CV type. For this reason, whether the weight of the final syllable in Italian might still play a role on stress assignment remains an open question.

Another important difference between the two languages is that Italian shows a two-way distinction of syllable weight of the type CVC, CVG, CGV, C/a/ > CV, while German shows a three-way distinction of the type CVCC, CVG > CVC, CVV > CV. This distinction relies in part on the different syllable structures of the two languages, since syllables with two consonants in the coda (CVCC) are allowed only in German, although the lack of CVCC syllables itself does not automatically exclude the possibility of a three-way system of syllable weight, for instance of the type CVG, CGV > CVC > CV. On the basis of these results, one possible line of research would be to analyze whether all languages that allow syllables with more than one consonant in the coda and show an influence of syllable weight on stress assignment also tend to develop a three-way contrast of syllable weight more often than languages that only allow syllables with one consonant in the coda as maximal syllable structure. Related to this aspect, another difference between the results of the Italian and German parts concerns the role of diphthongs in attracting stress. In Italian, diphthongs count as heavy as CVC syllables, while in German a falling diphthong (rising diphthongs are not present in German) counts as heavier than a CVC syllable. In spite of this difference, the results of both languages tend to support the hypothesis that if in a language a CVC syllable is heavy also a diphthong will be heavy, or possibly heavier, while the contrary, a language in which CVC syllables attract stress but diphthongs do not, seems less likely or perhaps impossible. This might possibly be due to the fact that syllables containing diphthongs could be regarded as more sonorous than CVC syllables, thus being positioned higher up in a hypothetical hierarchy of syllable weight. This hypothesis would be in line with Zec (1995)'s typological analysis, according to which if in a language less sonorous syllables, such as ending in an obstruent, are heavy this implies that also more sonorous syllables, such as ending in a sonorant or long vowel, will be heavy (see chapter 2.4).

The results obtained for Italian and German also differ considerably in the extent of the influence of syllable weight on stress. In the case of Italian, heavy syllables attract stress categorically (close to 100% of the times), while in German heavy syllables seem to attract stress about 50% of the times and superheavy syllables about 70% of the times. This difference might perhaps be partly explained by the fact that, in the case of 3-syllable words, in Italian a bimoraic foot is always built on the heavy syllables, as in L(H́)L, inevitably leaving the other syllables unparsed, while in German LLH words a double possibility exists which always allows full parsing, either (L̀L)(H́) or (ĹL)(H̀), which might in part account for the higher variability in stress placement when the final syllable is heavy or superheavy.

Concerning the effect of full parsing in 4-syllale words, both Italian and German overall show a tendency to achieve full parsing by placing stress on the penultimate syllable more often than in 3-syllable words, suggesting that perhaps the tendency to achieve full parsing occurs independently of how syllable weight works in a specific language.

Furthermore, for both languages, the results of the nonce word experiment have been overall confirmed by the results of the corpus analysis, indicating a strong relationship between the real lexicon and the mental algorithm for stress-assignment.

With respect to secondary stress, both Italian and German, besides sharing the same default position of primary stress as noted above, also share the same directionality of secondary stress from left to right. Interestingly, in both languages, the same types of syllables that attract primary stress also attract secondary stress, suggesting that, if primary stress is sensitive to syllable weight, also secondary stress tends to be sensitive to syllable weight in the same way, which is in line with the typological data also found for other languages (see chapter 2.4).

With respect to the acoustic analysis of primary and secondary stress, Italian and German show again some common elements and some important differences. In both languages the acoustic correlates of stress were measured in the vowel [a] in a word in accented condition. However, in the case of primary stress, the target words differed between Italian and German in both stress position and number of syllables, which might perhaps partly account for the differences in the results between the two languages. In the case of secondary stress, the target words had exactly the same structure in both languages, i.e. they were non-compound words of 4 or 5 syllables with secondary stress on the first syllable and primary stress on the penultimate syllable.

With respect to primary stress, in both Italian and German duration emerges as a clear correlate of stress. This is in line with typological data, which indicate duration as the most important acoustic correlate of stress cross-linguistically (Gordon & Röttger 2017, see chapter 11). Formant frequencies have also been found to be reliable correlates of primary stress in both languages, both F1 and F2 in German, but only F1 in Italian. This is also somewhat in line with expectations, since, according to typological data, formant frequencies represent the second most reliable correlate of stress cross-linguistically. The fact that F2 did not turn out to be a reliable correlate of stress in Italian suggests that perhaps, in the northern variety of Italian investigated in the present work, the stressed vowel [a] with respect to backness is realized somewhat in a central position, so that lack of stress does not cause further centralization on the horizontal axis. Intensity did not turn out to be a correlate of primary stress in either language, although the results for German seem to be strongly dependent on segmentation criteria (see chapter 15.4.1.2). In both Italian and German, the F0 contour of the carrier sentence seems to anchor to the primary stressed vowel of the target word in accented position, however in opposite ways between the two languages. In the case of German, F0 rises on the stressed vowel, while in the case of Italian it lowers on the stressed vowel. This difference might be due to the specific intonational contour produced by the German and Italian speakers. German speakers produced an overall decreasing F0 contour, in line with a declarative pattern, so it is to be expected that the primary stress of the target word causes an increase in F0 that disrupts the downwards contour. Italian speakers too produced an overall decreasing F0 contour, in line with a declarative pattern, which however ended with a sudden increase in F0 on the post-tonic syllables of the target word in final position, suggesting an intonational contour typical of a list-reading pattern. In the kind of F0 contour produced by the Italian speakers, the reason why the stressed vowel of the target word might be associated with the lowest F0 level could be that this pattern allows the stressed vowel to stand out with respect to the following post-tonic vowels, which, as mentioned, are associated with a strong increase in F0. Finally, spectral tilt turned out to be a reliable correlate of primary stress only in German. Since there is a high level of variability in how spectral tilt can be measured, it might be the case that a different measure of spectral tilt from the one used in this study will yield significant results also in Italian, thus supporting the hypothesis that the reliability of spectral tilt might vary widely cross-linguistically depending on how it is defined.

With respect to secondary stress, in the case of German all parameters that were found to be correlates of primary stress were also found to be correlates of secondary stress, with the exception of spectral tilt. Furthermore, the results for German indicated that secondary stress is realized more prominently in words with a longer interval in terms of number of syllables between primary and secondary stress in comparison to words with a shorter interval. In the case of Italian, on the contrary, the only effect concerning secondary stress was found for F0, which was found to rise on the secondary stress vowel of the target word in accented condition. However, as for primary stress, the results related to F0 can be considered valid only for an accented condition and cannot be generalized to other conditions, so they cannot be considered as reliable as the results for the other parameters. One tentative explanation of why the acoustic correlates of secondary stress emerged very clearly in German but not in Italian might be due to the fact that secondary stress might play a more prominent role in the German lexicon than in the Italian one. More specifically, the German lexicon exhibits a strong tendency towards compounding, leading to the presence of many compound words which might be interpreted as having a secondary stress on the syllable originally bearing a primary stress in one of the constituents of the compound. This phenomenon might perhaps lead to the tendency to produce a secondary stress more often in German than in Italian, in which compounding is not as widespread. Furthermore, it might be possible that secondary stress in compounds might be realized in an exceptionally prominent way, since it is the results of stress preservation from an original primary stress. This tendency to produce a strong secondary stress in compounds might then be extended also to non-compound words, like the ones that were used in the present experiment. Overall, if the hypothesis that secondary stress is produced more prominently in compound words than in non-compound words turns out to be true, it might be possible that analyzing secondary stress in compound words in Italian might yield more significant results with respect to its acoustic correlates.

Overall, it could be concluded that the stress systems of Italian and German share both similarities and significant differences. These findings underscore the complex ways in which language-specific phonological structures and prosodic patterns might diverge in the world's languages, in this case between two languages belonging to different branches of the Indo-European language family. Further research, also involving both comparison among genealogically closely related languages and non-related languages, might allow to obtain a more fine-grained understanding of how stress systems vary cross-linguistically.

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Appendix

Appendix (1). Summary of data of the Italian participants of both the nonce word experiment and the phonetic experiment.

ID	Sex	Age	Region	Second mother tongue/dialect
A1	m	56	Lazio	
A2	m	33	Trentino-Alto Adige	
A3	m	59	Veneto	
A4	f	62	Veneto	
A5	m	54	Veneto	
A6	m	63	Veneto	
A7	f	53	Trentino-Alto Adige	
A8	m	57	Lombardia[135]	Veronese dialect
A9	m	64	Veneto	
A10	f	62	Veneto	
A11	m	48	Veneto	Veronese dialect
A12	m	43	Veneto	Veronese dialect
A13	f	37	Veneto	
A14	m	20	Veneto	Veronese dialect
A15	m	24	Veneto	
A16	m	23	Veneto	
A17	f	20	Veneto	
A18	f	22	Lombardia	
A19	f	22	Veneto	
A20	f	24	Veneto	Veneto dialect
A21	f	22	Veneto	
A22	f	23	Veneto	Arabic
A23	f	20	Puglia	Pugliese dialect
A24	f	22	Lombardia	
A25	f	21	Veneto	
A26	m	30	Veneto	
A27	f	22	Veneto	
A28	f	27	Lombardia	
A29	f	30	Veneto	
A30	f	27	Lombardia	

[135] Participant A8 comes originally form Lombardia but has lived mostly in Veneto.

Appendix (2) Summary of data of the German participants of both the nonce word experiment and the phonetic experiment.

ID	**Sex**	**Age**	**Region**	**Second mother tongue/dialect**
D1	f	30	Bayern	Bayern dialect
D2	f	27	Baden-Württemberg	
D3	f	25	Hessen	
D4	m	26	Nordrhein-Westfalen	
D5	m	26	Sachsen-Anhalt	
D6	f	22	Baden-Württemberg	Swabian dialect
D7	f	29	Sachsen	
D8	f	24	Baden-Württemberg	Bodenseealemannisch
D9	f	28	Nordrhein-Westfalen	
D10	f	48	Nordrhein-Westfalen	
D11	f	24	Hessen	
D12	f	30	Hessen	
D13	f	26	Mecklenburg-Vorpommern	
D14	f	28	Hessen	
D15	m	29	Niedersachsen	
D16	f	24	Niedersachsen	
D17	f	20	Bayern	
D18	m	20	Baden-Württemberg	
D19	m	25	Hessen	
D20	f	21	Baden-Württemberg	
D21	f	42	Hessen	
D22	m	23	Bayern	
D23	f	37	Niedersachsen	
D24	f	26	Niedersachsen	
D25	f	22	Nordrhein-Westfalen	
D26	m	27	Hessen	
D27	f	23	Baden-Württemberg	
D28	f	25	Bayern	
D29	f	24	Nordrhein-Westfalen	
D30	f	24	Bayern	

Appendix (3). Nonce words, and their respective stress patterns, aimed at analyzing the influence of syllable weight on primary stress in Italian.

Diph. = diphthong, HF = historical factor.

Nonce word	Syllable structure	Weight type	Primary stress patterns		
			Total	A	P
fanabo	LLL	[none]	30	10	20
panafe	LLL	[none]	29	4	25
nevoba	LLL	[none]	29	5	24
selepa	LLL	[none]	30	4	26
pifuba	LLL	[none]	30	6	24
nifuvo	LLL	[none]	30	2	28
			178 (-2)	17.41% (31)	82.58% (147)
selnefo	HLL	Coda	29	3	26
zentofa	HLL	Coda	30	5	25
bantafe	HLL	Coda	29	2	27
dorroba	HLL	Coda	30	5	25
tannafa	HLL	Coda	29	6	23
nirtufa	HLL	Coda	29	1	28
			176 (-4)	12.50% (22)	87.50% (154)
selempa	LHL	Coda	30	0	30
lidunfe	LHL	Coda	29	0	29
falarta	LHL	Coda	29	0	29
nelocco	LHL	Coda	30	0	30
baraffo	LHL	Coda	29	0	29
vilunco	LHL	Coda	30	0	30
			177 (-3)	0% (0)	100% (177)
piavafo	HLL	Rising diph.	28	3	25
guelubo	HLL	Rising diph.	28	6	22
fualapo	HLL	Rising diph.	27	4	23
			83 (-7)	15.66% (13)	84.33% (70)
coriaba	LHL	Rising diph.	30	0	30
saruefo	LHL	Rising diph.	29	1	28
mafuapo	LHL	Rising diph.	29	0	29
			88 (-2)	1.13% (1)	98.86% (87)
lausifo	HLL	Falling diph.	29	3	26
reilepa	HLL	Falling diph.	30	3	27
tairiba	HLL	Falling diph.	30	1	29
			89 (-1)	7.86% (7)	92.13% (82)
rulauba	LHL	Falling diph.	20	0	20

daneipa	LHL	Falling diph.	29	0	29
nelaifa	LHL	Falling diph.	27	0	27
			76 (-14)	0% (0)	100% (76)
trafabo	HLL	Double onset	30	7	23
gremepa	HLL	Double onset	30	3	27
brinifo	HLL	Double onset	29	5	24
sfolope	HLL	Double onset	29	5	24
			118 (-2)	16.94% (20)	83.05% (98)
facrabe	LHL	Double onset	29	5	24
nodrefo	LHL	Double onset	30	2	28
gebrepa	LHL	Double onset	28	3	25
natrabo	LHL	Double onset	30	5	25
			117 (-3)	12.82% (15)	87.17% (102)
sprafabe	HLL	Triple onset	29	4	25
sgrevepa	HLL	Triple onset	30	2	28
sfrumuvo	HLL	Triple onset	28	3	25
splonofa	HLL	Triple onset	30	4	26
			117 (-3)	11.11% (13)	88.88% (104)
rasifa	HLL	Vowel sonority	30	6	24
farupo	HLL	Vowel sonority	30	4	26
talubo	HLL	Vowel sonority	30	3	27
			90 (-0)	14.44% (13)	85.55% (77)
nifapo	LHL	Vowel sonority	30	2	28
cuvafe	LHL	Vowel sonority	30	0	30
sinapa	LHL	Vowel sonority	30	5	25
			90 (-0)	7.77% (7)	92.22% (83)
clefoda	HLL	HF (cluster)	29	5	24
psanafo	HLL	HF (cluster)	28	6	22
glemepa	HLL	HF (cluster)	30	3	27
pnalabo	HLL	HF (cluster)	30	4	26
			117 (-3)	15.38% (18)	84.61 (99)
seluoba	LHL	HF (diph.)	27	0	27
rimiefa	LHL	HF (diph.)	30	0	30
faguopa	LHL	HF (diph.)	29	0	29
galiepo	LHL	HF (diph.)	30	0	30
			116 (-4)	0% (0)	100% (116)
Pafalabo	LLLL	[none]	27	1	26
Meronefa	LLLL	[none]	28	0	28
Losorepe	LLLL	[none]	30	1	29
Gurimudo	LLLL	[none]	26	1	25
Bituripo	LLLL	[none]	30	17	13

			141 (-9)	14.18% (20)	85.81% (121)
			111 (-9) No *Bituripo*	2.70% (3)	97.29% (108)
garalcafo	LHLL	Coda	28	4	24
marannabo	LHLL	Coda	25	2	23
lorembofa	LHLL	Coda	28	3	25
beroffobe	LHLL	Coda	30	7	23
diluntufa	LHLL	Coda	30	3	27
			141 (-9)	13.47% (19)	86.52% (122)
faralango	LLHL	Coda	30	0	30
ramanatto	LLHL	Coda	30	0	30
porenelca	LLHL	Coda	29	0	29
leneroffa	LLHL	Coda	30	0	30
nivugurta	LLHL	Coda	30	0	30
			149 (-1)	0% (0)	100% (149)
rulianepo	LHLL	Rising diph.	27	1	26
faruatefa	LHLL	Rising diph.	29	1	28
baruesapa	LHLL	Rising diph.	29	1	28
			85 (-5)	3.52% (3)	96.47% (82)
gonariafo	LLHL	Rising diph.	28	0	28
reboluabe	LLHL	Rising diph.	26	0	26
siranuepa	LLHL	Rising diph.	29	0	29
			83 (-7)	0% (0)	100% (83)
Gataurafo	LHLL	Falling diph.	26	1	26
vareinupe	LHLL	Falling diph.	26	3	26
laraibofa	LHLL	Falling diph.	26	3	26
			85 (-5)	8.23% (7)	91.76% (78)
lenoraufa	LLHL	Falling diph.	28	0	28
mureneiba	LLHL	Falling diph.	30	0	30
zanoraipo	LLHL	Falling diph.	29	0	29
			87 (-3)	0% (0)	100% (87)

Appendix (4). Nonce words, and their respective stress patterns, aimed at analyzing the influence of syllable weight on secondary stress in Italian.

Diph. = diphthong, HF = historical factor.

Nonce word	Syllable structure	Weight type	Secondary stress patterns		
			Total	**1° σ**	**2° σ**
Malaramento	LLLY	[none]	30	24	6
Pasarazione	LLLY	[none]	28	26	2
Ferotazione	LLLY	[none]	29	27	2
Loneramento	LLLY	[none]	28	25	3
Gupirezione	LLLY	[none]	23	22	1
Pilurità	LLLY	[none]	28	17	11
			166 (-14)	84.93% (141)	15.06% (25)
Larancamento	LHLY	Coda	30	4	26
Carattazione	LHLY	Coda	30	0	30
Beroffamento	LHLY	Coda	23	3	20
Gosertazione	LHLY	Coda	29	5	24
Vurissazione	LHLY	Coda	23	3	20
Pirulsità	LHLY	Coda	28	0	28
			163 (-17)	9.20% (15)	90.79% (148)
Farienomento	LHLY	Rising diph.	20	11	9
Lumiarezione	LHLY	Rising diph.	20	13	7
Meruolità	LHLY	Rising diph.	20	11	9
			60 (-30)	58.33% (35)	41.66% (25)
Milauramento	LHLY	Falling diph.	26	3	23
Gulairazione	LHLY	Falling diph.	25	4	21
Boleinità	LHLY	Falling diph.	24	8	16
			75 (-15)	20% (15)	80% (60)
Tacranomento	LHLY	Double onset	18	10	8
Gafralazione	LHLY	Double onset	28	26	2
Lebrenazione	LHLY	Double onset	28	20	8
Pitrubità	LHLY	Double onset	26	13	13
			100 (-20)	69% (69)	31% (31)

Appendix (5). Filler nonce words of the nonce word experiment in Italian.

danco	rastico	gusso	rentico	ferla	gorico	laroso
lanice	gartice	rulità	narpo	rinoso	rontico	gafità
milutà	fupice	raco	nertico	lanco	maco	

Appendix (6). Nonce words, and their respective stress patterns, aimed at analyzing the influence of syllable weight on primary stress in German.

Fall. diph. = falling diphthong; Dbl. onset = double onset; V. length = vowel length

Nonce word	Syllable structure	Weight type		Primary stress patterns		
			Total	A	P	F
Bafa	LL	[none]	30		30	0
Lero	LL	[none]	30		30	0
Pifu	LL	[none]	30		30	0
Fopo	LL	[none]	30		30	0
			120		100% (120)	0% (0)
Ferpo	HL	Coda	30		30	0
Manka	HL	Coda	30		30	0
Rolpi	HL	Coda	25		25	0
			85 (-5)		100% (85)	0% (0)
Fakaf	LH	Coda	30		15	15
Selop	LH	Coda	30		21	9
Gurok	LH	Coda	25		22	3
			85 (-5)		68,23% (58)	31,76% (27)
Teboto	LLL	[none]	30	1	29	0
Ribufi	LLL	[none]	29	1	28	0
Farapa	LLL	[none]	29	2	27	0
Moloro	LLL	[none]	29	2	27	0
Sapofa	LLL	[none]	29	2	26	1
Lerubi	LLL	[none]	30	1	28	1
			176 (-4)	5,11% (9)	93,75% (165)	1,13% (2)
Mafini	HLL	Vowel sonority	30	2	28	0
Palufu	HLL	Vowel sonority	29	1	27	1
Sanuri	HLL	Vowel sonority	29	0	29	0
			88 (-2)	3,40% (3)	95,45% (84)	1,13% (1)
Gurapi	LHL	Vowel sonority	30	1	28	1
Bilafi	LHL	Vowel sonority	30	1	28	1
Tumaki	LHL	Vowel sonority	29	0	29	0
			89 (-1)	2,24% (2)	95,50% (85)	2,24% (2)
Piluna	LLH	Vowel sonority	30	0	30	0
Ridipa	LLH	Vowel sonority	30	5	23	2
Mufila	LLH	Vowel sonority	30	5	25	0
			90 (-0)	11,11% (10)	86,66% (78)	2,22% (2)
Palsara	HLL	Coda	30	1	29	0

Lonsoto	HLL	Coda	30	1	29	0
Fasbora	HLL	Coda	30	0	30	0
Merpafo	HLL	Coda	30	5	25	0
			120 (-0)	5,83% (7)	94,16% (113)	0% (0)
Rifulpi	LHL	Coda	30	1	29	0
Watanka	LHL	Coda	30	0	30	0
Nelamfi	LHL	Coda	30	0	25	5
Pigurko	LHL	Coda	30	0	29	1
			120 (-0)	0,83% (1)	94,16% (113)	5% (6)
Bogorok	LLH	Coda	29	12	7	10
Misulif	LLH	Coda	30	4	8	18
Pelasot	LLH	Coda	25	4	0	21
Ranakon	LLH	Coda	30	13	6	11
			114 (-6)	28,94% (33)	18,42% (21)	52,63% (60)
Reloponk	LLH	Complex coda	29	6	3	20
Wasanast	LLH	Complex coda	30	2	1	27
Dimarolt	LLH	Complex coda	30	5	1	24
Mefonurk	LLH	Complex coda	30	5	3	22
			119 (-1)	15,12% (18)	6,7% (8)	78,15% (93)
Laufaka	HLL	Falling diph.	30	3	27	0
Reigona	HLL	Falling diph.	23	1	22	0
Maikofo	HLL	Falling diph.	25	1	23	1
			78 (-12)	6,41% (5)	92,3% (72)	1,28% (1)
Topaufo	LHL	Falling diph.	30	0	28	2
Sifeilo	LHL	Falling diph.	26	2	24	0
Karaipa	LHL	Falling diph.	25	0	25	0
			81 (-9)	2,46% (2)	95,06% (77)	2,46% (2)
Veralau	LLH	Falling diph.	30	1	3	26
Gerotau	LLH	Falling diph.	29	5	3	21
Bifurai	LLH	Falling diph.	24	2	3	19
			83 (-7)	9,63% (8)	10,84% (9)	79,51% (66)
Speroto	HLL	Double onset	27	1	26	0
Fralapa	HLL	Double onset	29	4	25	0
Knirupi	HLL	Double onset	25	1	24	0
			81 (-9)	7,40% (6)	92,59% (75)	0% (0)
Pakrafa	LHL	Double onset	30	3	27	0
Ripludi	LHL	Double onset	28	3	25	0
Geklopo	LHL	Double onset	24	1	23	0
			82 (-8)	8,53% (7)	91,46% (75)	0% (0)
Nepofro	LLH	Double onset	27	2	21	4

Galapra	LLH	Double onset	30	2	25	3
Wupitri	LLH	Double onset	23	4	18	1
			80 (-10)	10% (8)	80% (64)	10% (8)
Strafala	HLL	Triple onset	27	3	24	0
Spretobo	HLL	Triple onset	29	4	25	0
Skribuli	HLL	Triple onset	25	12	13	0
			81 (-9)	23,45% (19)	76,54% (62)	0% (0)
			(no skribuli)	12,5% (7)	87,5% (49)	0% (0)
Fehrofo	HLL	Vowel length	30	2	28	0
Rahloko	HLL	Vowel length	25	2	22	1
			55 (-5)	7,27% (4)	90,90% (50)	1,81% (1)
Gasahra	LHL	Vowel length	30	0	28	2
Manehla	LHL	Vowel length	25	0	25	0
			55 (-5)	0% (0)	96,36% (53)	3,63% (2)
Palagah	LLH	Vowel length	25	3	9	13
Loforeh	LLH	Vowel length	25	3	2	20
			50 (-10)	12% (6)	22% (11)	66% (33)
Ralonfop	LHH	Coda + coda	22	3	9	10
Merolpok	LHH	Coda + coda	24	6	5	13
Fibutpon	LHH	Coda + coda	24	3	5	16
			70 (-20)	17,14% (12)	27,14% (19)	55,71% (39)
Malaifop	LHH	Fall. diph. + Coda	22	1	8	13
Leraunof	LHH	Fall. diph. + Coda	22	1	15	6
Woraikon	LHH	Fall. diph. + Coda	25	3	15	7
			69 (-21)	7,24% (5)	55,07% (38)	37.68% (26)
Regrefon	LHH	Dbl. Onset + Coda	25	7	4	14
Satragal	LHH	Dbl. Onset + Coda	24	2	7	15
Gukrifup	LHH	Dbl. Onset + Coda	23	15	5	3
			72 (-18)	33,33% (24)	22,22% (16)	44,44% (32)
Falohrog	LHH	V. length + Coda	24	5	7	12
Palahran	LHH	V. length + Coda	25	3	12	10
Gerehnof	LHH	V. length + Coda	25	11	8	6
			74 (-16)	25,67% (19)	36,48% (27)	37,83% (28)
Meporoto	LLLL	[none]	30	3	27	0
Nufisuri	LLLL	[none]	29	0	29	0
Kopariga	LLLL	[none]	29	1	28	0
			88 (-2)	4,54% (4)	95,45% (84)	0% (0)
Balankasa	LHLL	Coda	30	2	28	0

Folorpono	LHLL	Coda	30	1	29	0
Raniktopa	LHLL	Coda	29	0	29	0
			89 (-1)	3,37% (3)	96,62% (86)	0% (0)
Kifupunki	LLHL	Coda	28	0	28	0
Ganafarta	LLHL	Coda	29	0	29	0
Wurilapto	LLHL	Coda	30	0	30	0
			87 (-3)	0% (0)	100% (87)	0% (0)
Serogopot	LLLH	Coda	28	0	5	23
Murilubin	LLLH	Coda	30	0	7	23
Mafanuras	LLLH	Coda	25	1	22	2
			83 (-7)	1,20% (1)	40,96% (34)	57,83% (48)
Rifauliri	LHLL	Falling diph.	29	1	28	0
Goleirofa	LHLL	Falling diph.	28	1	27	0
Segainuro	LHLL	Falling diph.	25	0	25	0
			82 (-8)	2,43% (2)	97,56% (80)	0% (0)
Mesolaupo	LLHL	Falling diph.	29	0	29	0
Soraneifa	LLHL	Falling diph.	29	0	29	0
Werunaiko	LLHL	Falling diph.	25	0	25	0
			83 (-7)	0% (0)	100% (83)	0% (0)
Gafanarau	LLLH	Falling diph.	26	1	7	18
Nurimalei	LLLH	Falling diph.	30	0	5	25
Peromotai	LLLH	Falling diph.	25	0	2	23
			81 (-9)	1,23% (1)	17,28% (14)	81,48% (66)
Wulatorink	LLLH	Complex coda	28	1	12	15
Bafanolark	LLLH	Complex coda	28	1	4	23
Dilunorast	LLLH	Complex coda	25	0	2	23
			81 (-9)	2,46% (2)	22,22% (18)	75,30% (61)

Appendix (7). Nonce words, and their respective stress patterns, aimed at analyzing the influence of syllable weight on secondary stress in German.

Diph. = diphthong.

Nonce word	Syllable structure	Weight type	Secondary stress patterns		
			Total	**1° σ**	**2° σ**
Malakorismus	LLLY	[none]	30	22	8
Perotulieren	LLLY	[none]	30	25	5
Fupitanismus	LLLY	[none]	27	25	2
Sanafelieren	LLLY	[none]	30	22	8
			117 (-3)	80,34% (94)	19,6% (23)
Rodenkolieren	LHLY	Coda	30	21	9
Laparfolismus	LHLY	Coda	27	19	8
Nisufkonieren	LHLY	Coda	24	7	17
Boroptarismus	LHLY	Coda	28	2	26
			109 (-11)	44,95% (49)	55,04% (60)
Taraupolismus	LHLY	Falling diph.	29	4	25
Peraukosieren	LHLY	Falling diph.	30	9	21
Nureimelismus	LHLY	Falling diph.	23	4	19
Fareutenieren	LHLY	Falling diph.	26	3	23
			108 (-12)	18,51% (20)	81,48% (88)
Maprafelismus	LHLY	Double onset	26	23	3
Setrolanieren	LHLY	Double onset	26	21	5
Ruplisedismus	LHLY	Double onset	26	21	5
Taflaminieren	LHLY	Double onset	27	21	6
			105 (-15)	81,90% (86)	18,09% (19)

Appendix (8). Filler nonce words of the nonce word experiment in German.

Gerkeit	Fehnung	Gahnigkeit	Pfaltung	Mürenheit	Gunkel	Manität
Plinzt	Feunterlich	Groch	Lährig	Korimapeilanieren	Lürenheit	Künerei
Sährligkeit	Gupferkeit	Börichlein	Mackel	Maniropoltasieren	Grischkeit	Zahrenheit
Froch	Pröschel	Müreintum	Sterf	Felanataunarismus	Mienterlich	Baunität
Rählung	Döffig	Rudentum	Gäufenlich	Balafurinkorismus	Fäulist	Pahrenheit
Lättertum	Rölant					

Appendix (9). Real words aimed at analyzing the acoustic correlates of primary and secondary stress in Italian + fillers.

PS = primary stress; SS = secondary stress

Level of stress analyzed	**Real Word**	**Stress position**	**Notes**
Primary stress	canapa	PS on the antepenult	
	patata	PS on the penult	
	maragià	PS on the final	
Secondary stress	catalano	SS on the first syllable. PS on the penult	Inter-stress interval of 1 syllable
	catamarano	SS on the first syllable PS on the penult	Inter-stress interval of 2 syllables

Fillers of the phonetic experiment on Italian			
tavolo	edificio	ricordo	relazione
telefono	regalo	limite	sole

Appendix (10). Real words aimed at analyzing the acoustic correlates of primary and secondary stress in German + fillers.

PS = primary stress; SS = secondary stress

Level of stress analyzed	**Real Word**	**Stress position**	**Notes**
Primary stress	Papa	PS on the first syllable	2 syllables in total
	Panama	PS on the first syllable	3 syllables in total
Secondary stress	Fanatismus	SS on the first syllable. PS on the penult	Inter-stress interval of 1 syllable
	katalysieren	SS on the first syllable PS on the penult	Inter-stress interval of 2 syllables

Fillers of the phonetic experiment on German			
Schlüssel	Anfang	Schule	Wahrheit
Bewegung	Lampe	Haus	hilfreich

Appendix (11). Results of the chi-square tests of the nonce word experiment in Italian.

Ris. diph. = rising diphthong; Fall. diph. = falling diphthong; Dbl. onset = double onset

Condition	**χ^2 value**	**df**	**p-value**	**N**
(2.) HLL-Coda vs LLL	1.68	1	0.195	354
(3.) LHL-Coda vs LLL	19.6	1	< .001	278
(4.) HLL-Rising diphthong vs LLL	0.124	1	0.725	261
(5.) LHL-Rising diphthong vs LLL	14.7	1	< .001	266
(6.) HLL-Falling diphthong vs LLL	4.43	1	0.35	267
(7.) LHL-Falling diphthong vs LLL	19.6	1	< .001	278
(8.) HLL-Vowel sonority vs LLL	0.385	1	0.535	268
(9.) LHL-Vowel sonority vs LLL	4.56	1	0.033	268
(10.) HLL-Double onset vs LLL	0.0108	1	0.917	296
(11.) LHL-Double onset vs LLL	1.13	1	0.287	295
(12.) HLL-Triple onset vs LLL	2.21	1	0.137	295
(13.) HLL-Historical onset vs LLL	0.210	1	0.647	295
(14.) LHL-Historical diphthong vs LLL	22.6	1	< .001	294
(16.) LHLL-Coda vs LLLL	0.0298	1	0.863	282
(17.) LLHL-Coda vs LLLL	22.7	1	< .001	290
(18.) LHLL-Rising diphthong vs LLLL	6.59	1	0.010	226
(19.) LLHL-Rising diphthong vs LLLL	12.9	1	< .001	224
(20.) LHLL-Falling diphthong vs LLLL	1.78	1	0.182	226
(21.) LLHL-Falling diphthong vs LLLL	13.5	1	< .001	228
LLL vs LLLL	0.612	1	0.434	319
LLL vs LLLL (without *bituripo*)	14.3	1	< .001	289
HLL-Coda vs LHLL-Coda	0.0661	1	0.797	317
LHL-Coda vs LLHL-Coda	[not applicable]			
HLL-Ris. diph. vs LHLL-Ris. diph.	7.17	1	0.007	168
LHL-Ris. diph. vs LLHL-Ris. diph.	0.949	1	0.330	171
HLL-Fall. diph. vs LHLL-Fall. diph.	0.00805	1	0.929	174
LHL-Fall. diph. vs LLHL-Fall. diph.	[not applicable]			
(23.) LHLY(X)-Coda vs LLLY(X)	189	1	< .001	329
(24.) LHLY(X)-Ris. diph. vs LLLY(X)	18.1	1	< .001	226
(25.) LHLY(X)-Fall. diph. vs LLLY(X)	95.4	1	< .001	241
(26.) LHLY(X)-Dbl. onset vs LLLY(X)	9.54	1	0.002	266
LHLY(X)-Coda vs LHLY(X)-Fall. diph.	5.44	1	0.020	238

Appendix (12). Results of the chi-square tests of the nonce word experiment in German.

Fall. diph. = falling diphthong; Dbl. onset = double onset; Dbl. coda = double coda

Condition	χ^2 value	df	p-value	N
(2.) HL-Coda vs LL	[not applicable]			
(3.) LH-Coda vs LL	43.9	1	< .001	205
LL vs LLL	7.79	2	0.020	296
HL-Coda vs LHL-Coda	5.13	2	0.077	205
LH-Coda vs LLH-Coda	59.9	2	< .001	199
(5.) HLL-Coda vs LLL	1.43	2	0.488	296
(6.) LHL-Coda vs LLL	7.81	2	0.020	296
(7.) LLH-Coda vs LLL	174	2	< .001	290
(8.) LLH-Double Coda vs LLL	230	2	< .001	295
(9.) HLL-Falling diphthong vs LLL	0.187	2	0.911	254
(10.) LHL-Falling diphthong vs LLL	1.55	2	0.461	257
(11.) LLH-Falling diphthong vs LLL	191	2	< .001	259
(12.) HLL-Vowel length vs LLL	0.533	2	0.766	231
(13.) LHL-Vowel length vs LLL	4.36	2	0.113	231
(14.) LLH-Vowel length vs LLL	134	2	< .001	226
(15.) HLL-Vowel sonority vs LLL	0.393	2	0.822	264
(16.) LHL-Vowel sonority vs LLL	1.67	2	0.433	265
(17.) LLH-Vowel sonority vs LLL	0.393	2	0.822	264
(18.) HLL-Double onset vs LLL	1.43	2	0.490	257
(19.) LHL-Double onset vs LLL	2.02	2	0.364	258
(20.) LLH-Double onset vs LLL	14.2	2	< .001	256
(21.) HLL-Triple onset vs LLL	19.9	2	< .001	257
HLL-Triple onset (no *skribuli*) vs LLL	4.18	4	0.001	232
(22.) LHH-Coda+Coda vs LLH-Coda	4.07	2	0.131	184
(23.) LHH-Fall. Diph.+Coda vs LLH-Coda	29.7	2	< .001	183
(24.) LHH-Dbl. onset+Coda vs LLH-Coda	1.20	2	0.550	18
(25.) LHH-Vowel length+Coda vs LLH-Coda	8.01	2	0.018	188
(27.) LHLL-Coda vs LLLL	0.161	1	0.688	177
(28.) LLHL-Coda vs LLLL	4.05	1	0.044	175
(29.) LLLH-Coda vs LLLL	70.9	2	< .001	171
(30.) LLLH-Double coda vs LLLL	104	2	< .001	169
(31.) LHLL-Falling diph. vs LLLL	0.553	1	0.457	170
(32.) LLHL-Falling diph.vs LLLL	3.86	1	0.049	171
(33.) LLLH-Falling diph. vs LLLL	118	2	< .001	169
LLL vs LLLL	1.06	2	0.590	264
HLL-Coda vs LHLL-Coda	0.680	1	0.410	209
LHL-Coda vs LLHL-Coda	5.25	2	0.072	207
LLH-Coda vs LLLH-Coda	30.4	2	< .001	197
LLH-Dbl. Coda vs LLLH-Dbl. Coda	16.7	2	< .001	200
HLL- Fall.diph vs LHLL-Fall. diph	2.61	2	0.271	160

LHL-Fall. diph vs LLHL-Fall. diph	4.20	2	0.122	164
LLH-Fall. diph vs LLLH-Fall. diph	6.51	2	0.039	164
LLLH-Coda vs LLLH-Double coda	6.78	2	0.034	164
LLLH-Coda vs LLLH-Fall. diph	11.2	2	0.004	164
(35.) LHLY(X)-Coda vs LLLY(X)	30.4	1	< .001	226
(36.) LHLY(X)-Fall. diph. vs LLLY(X)	85.9	1	< .001	225
(37.) LHLY(X)-Dbl. onset vs LLLY(X)	0.0881	1	0.767	222
LHLY(X)-Coda vs LHLY(X)-Fall. diph.	17.5	1	< .001	217

Appendix (13). Results of the chi-square tests of the comparison between the results of the nonce word experiment and of the corpus analysis in Italian.

Ris. diph. = rising diphthong; Fall. diph. = falling diphthong; Dbl. onset = double onset

Condition	**χ^2 value**	**df**	**p-value**	**N**
(1.) LLL	14.2	1	< .001	1144
(2.) HLL-Coda	19.9	1	< .001	1296
(3.) LHL-Coda	0.374	1	0.541	636
(4.) HLL-Rising diphthong	1.28	1	0.258	153
(5.) LHL-Rising diphthong	1.00	1	0.317	177
(6.) HLL-Falling diphthong	5.79	1	0.016	98
(7.) LHL-Falling diphthong	[not applicable]			
(8.) HLL-Vowel sonority	15.0	1	< .001	194
(9.) LHL-Vowel sonority	0.000474	1	0.983	179
(10.) HLL-Double onset	4.58	1	0.032	470
(11.) LHL-Double onset	0.770	1	0.380	236
(12.) HLL-Triple onset	3.39	1	0.065	151
(13.) HLL-Historical onset	11.3	1	< .001	141
(14.) LHL-Historical diphthong	[not applicable]			
(15.) LLLL	14.3	1	< .001	988
(16.) LHLL-Coda	9.12	1	0.003	621
(17.) LLHL-Coda	0.422	1	0.516	503
(18.) LHLL-Rising diphthong	21.7	1	< .001	134
(19.) LLHL-Rising diphthong	[not applicable]			
(20.) LHLL-Falling diphthong	[not applicable]			
(21.) LLHL-Falling diphthong	[not applicable]			

Appendix (14). Results of the chi-square tests of the comparison between the results of the nonce word experiment and of the corpus analysis in German.

Condition	**χ^2 value**	**df**	**p-value**	**N**
(1.) LL	0.826	1	0.363	558
(2.) HL-Coda	0.949	1	0.330	356
(3.) LH-Coda	9.98	1	0.002	1394
(3b.) LH-Coda (no suffixes)	3.76	1	0.053	1128
(4.) LLL	2.42	2	0.299	355
(5.) HLL-Coda	0.319	1	0.572	196
(6.) LHL-Coda	2.70	2	0.259	160
(7.) LLH-Coda	15.0	2	< .001	704
(7b.) LLH-Coda (no suffixes)	2.13	2	0.345	562
(8.) LLH-Double Coda	4.21	2	0.122	235
(9.) HLL-Falling diphthong	[not applicable]			
(10.) LHL-Falling diphthong	[not applicable]			
(11.) LLH-Falling diphthong	18.7	2	< .001	165
(12.) HLL-Vowel length	[not applicable]			
(13.) LHL-Vowel length	[not applicable]			
(14.) LLH-Vowel length	7.26	2	0.27	75
(15.) HLL-Vowel sonority	[not applicable]			
(16.) LHL-Vowel sonority	[not applicable]			
(17.) LLH-Vowel sonority	[not applicable]			
(18.) HLL-Double onset	0.390	1	0.532	125
(19.) LHL-Double onset	2.19	1	0.139	106
(20.) LLH-Double onset	[not applicable]			
(21.) HLL-Triple onset	[not applicable]			
(22.) LHH-Coda+Coda	21.3	2	< .001	238
(22b.) LHH-Coda+Coda (no suffixes)	10.9	2	0.004	206
(23.) LHH-Falling diphthong+Coda	[not applicable]			
(24.) LHH-Double onset+Coda	1.67	2	0.435	117
(25.) LHH-Vowel length+Coda	85.0	2	< .001	171
(26.) LLLL	1.68	1	0.195	171
(27.) LHLL-Coda	2.78	1	0.095	104
(28.) LLHL-Coda	[not applicable]			
(29.) LLLH-Coda	9.63	2	0.008	285
(29b.) LLLH-Coda (no suffixes)	2.54	2	0.281	212
(30.) LLLH-Double coda	5.36	2	0.069	100
(31.) LHLL-Falling diphthong	[not applicable]			
(32.) LLHL-Falling diphthong	[not applicable]			
(33.) LLLH-Falling diphthong	[not applicable]			

Appendix (15). Regular expressions used to retrieve the target words in the corpus analysis on Italian. The symbols representing the phonemes are IPA characters. The numbers 1, 2, 3 and 4 refers to the syllables within the word counting from the right. Stress on a specific syllable is added by adding the symbol ‘ ' ’ after the number referring to that syllable.

Condition	**Regular expression**
(1.) LLL	3?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]2?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]1?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø](?!.+)
(2.) HLL-Coda	3?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø][pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ]2?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]1?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø](?!.+)
(3.) LHL-Coda	3?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]2?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø][pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ]1?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø](?!.+)
(4.) HLL-Rising diphthong	3?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][jw][aeɛoɔiuø]2?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]1?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø](?!.+)
(5.) LHL-Rising diphthong	3?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]2?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][jw][aeɛoɔiuø]1?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø](?!.+)
(6.) HLL-Falling diphthong	3?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø][jw]2?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]1?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø](?!.+)
(7.) LHL-Falling diphthong	3?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]2?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø][jw]1?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø](?!.+)
(8.) HLL-Vowel sonority	3?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][a]2?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][iu]1?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø](?!.+)
(9.) LHL-Vowel sonority	3?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][iu]2?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][a]1?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø](?!.+)
(10.) HLL-Double onset	3'?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ]{2}[aeɛoɔiuø]2'?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]1'?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø](?!.+)
(11.) LHL-Double onset	3'?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]2'?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ]{2}[aeɛoɔiuø]1'?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø](?!.+)
(12.) HLL-Triple onset	3?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ]{3}[aeɛoɔiuø]2?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]1?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø](?!.+)
(13.) HLL-Historical onset	3?([pbtdkl]{2}|ps|ks)[aeɛoɔiuø]2?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]1?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø](?!.+)
(14.) LHL-Historical diphthong	3?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]2?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][jw][eɛoɔ]1?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø](?!.+)
(15.) LLLL	4[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]3?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]2?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]1?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø](?!.+)
(16.) LHLL-Coda	4[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]3?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø][pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ]2?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]1?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø](?!.+)
(17.) LLHL-Coda	4[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]3?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]2?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø][pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ]1?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø](?!.+)
(18.) LHLL-Rising diphthong	4[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]3?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][jw][aeɛoɔiuø]2?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]1?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø](?!.+)
(19.) LLHL-Rising diphthong	4[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]3?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]2?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][jw][aeɛoɔiuø]1?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø](?!.+)
(20.) LHLL-Falling diphthong	4[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]3?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø[jw]]2?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]1?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø](?!.+)
(21.) LLHL-Falling diphthong	4[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]3?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø]2?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø][jw]1?[pbtdkgʦʣʧʤfvszʃlrmnɲʎʒ][aeɛoɔiuø](?!.+)

Appendix (16). Regular expressions used to retrieve the target words in the corpus analysis on German. The symbols representing the phonemes are SAMPA characters. The numbers 1, 2, 3 and 4 refers to the syllables within the word counting from the right. Stress on a specific syllable is added by adding the symbol ‘ ' ’ after the number referring to that syllable.

<table>
<tr><th>Condition</th><th>Regular expression</th></tr>
<tr><td>(1.) LL</td><td>(?<!.)2[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]1[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^](?!.)</td></tr>
<tr><td>(2.) HL-Coda</td><td>(?<!.)2[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^][J_=\+rlmnNpbkgtdszSZfvxhjw]1[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^](?!.)</td></tr>
<tr><td>(3.) LH-Coda</td><td>(?<!.)2[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]1[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^][J_=\+rlmnNpbkgtdszSZfvxhjw](?!.)</td></tr>
<tr><td></td><td></td></tr>
<tr><td>(4.) LLL</td><td>(?<!.)3[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]2[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]1[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^](?!.)</td></tr>
<tr><td>(5.) HLL-Coda</td><td>(?<!.)3[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^][J_=\+rlmnNpbkgtdszSZfvxhjw]2[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]1[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^](?!.)</td></tr>
<tr><td>(6.) LHL-Coda</td><td>(?<!.)3[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]2[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^][J_=\+rlmnNpbkgtdszSZfvxhjw]1[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^](?!.)</td></tr>
<tr><td>(7.) LLH-Coda</td><td>(?<!.)3[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]2[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]1[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^][J_=\+rlmnNpbkgtdszSZfvxhjw](?!.)</td></tr>
<tr><td>(8.) LLH-Double Coda</td><td>(?<!.)3[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]2[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]1[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^][J_=\+rlmnNpbkgtdszSZfvxhjw]{2}(?!.)</td></tr>
<tr><td>(9.) HLL-Falling diphthong</td><td>(?<!.)3[J_=\+rlmnNpbkgtdszSZfvxhjw][BXW]2[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]1[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^](?!.)</td></tr>
<tr><td>(10.) LHL-Falling diphthong</td><td>(?<!.)3[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]2[J_=\+rlmnNpbkgtdszSZfvxhjw][BXW]1[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^](?!.)</td></tr>
<tr><td>(11.) LLH-Falling diphthong</td><td>(?<!.)3[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]2[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]1[J_=\+rlmnNpbkgtdszSZfvxhjw][BXW](?!.)</td></tr>
<tr><td>(12.) HLL-Vowel length</td><td>(?<!.)3[J_=\+rlmnNpbkgtdszSZfvxhjw][aiuoe\)\|y]2[J_=\+rlmnNpbkgtdszSZfvxhjw][&IUOE\/@Yaiuoe\)\|y]1[J_=\+rlmnNpbkgtdszSZfvxhjw][&IUOE\/@Yaiuoe\)\|y](?!.)</td></tr>
<tr><td>(13.) LHL-Vowel length</td><td>(?<!.)3[J_=\+rlmnNpbkgtdszSZfvxhjw][&IUOE\/@Yaiuoe\)\|y]2[J_=\+rlmnNpbkgtdszSZfvxhjw][aiuoe\)\|y]1[J_=\+rlmnNpbkgtdszSZfvxhjw][&IUOE\/@Yaiuoe\)\|y](?!.)</td></tr>
<tr><td>(14.) LLH-Vowel length</td><td>(?<!.)3[J_=\+rlmnNpbkgtdszSZfvxhjw][&IUOE\/@Yaiuoe\)\|y]2[J_=\+rlmnNpbkgtdszSZfvxhjw][&IUOE\/@Yaiuoe\)\|y]1[J_=\+rlmnNpbkgtdszSZfvxhjw][aiuoe\)\|y](?!.)</td></tr>
<tr><td>(15.) HLL-Vowel sonority</td><td>(?<!.)3[J_=\+rlmnNpbkgtdszSZfvxhjw][a&]2[J_=\+rlmnNpbkgtdszSZfvxhjw][iIuU]1[J_=\+rlmnNpbkgtdszSZfvxhjw][iIuU](?!.)</td></tr>
<tr><td>(16.) LHL-Vowel sonority</td><td>(?<!.)3[J_=\+rlmnNpbkgtdszSZfvxhjw][iIuU]2[J_=\+rlmnNpbkgtdszSZfvxhjw][a&]1[J_=\+rlmnNpbkgtdszSZfvxhjw][iIuU](?!.)</td></tr>
<tr><td>(17.) LLH-Vowel sonority</td><td>(?<!.)3[J_=\+rlmnNpbkgtdszSZfvxhjw][iIuU]2[J_=\+rlmnNpbkgtdszSZfvxhjw][iIuU]1[J_=\+rlmnNpbkgtdszSZfvxhjw][a&](?!.)</td></tr>
<tr><td>(18.) HLL-Double onset</td><td>(?<!.)3[J_=\+rlmnNpbkgtdszSZfvxhjw]{2}[a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]2[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]1[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^](?!.)</td></tr>
</table>

<table>
<tr><td>(19.) LHL-Double onset</td><td>(?<!.)3[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]2[J_=\+rlmnNpbkgtdszSZfvxhjw]{2}[a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]1[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^](?!.)</td></tr>
<tr><td>(20.) LLH-Double onset</td><td>(?<!.)3[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]2[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]1[J_=\+rlmnNpbkgtdszSZfvxhjw]{2}[a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^](?!.)</td></tr>
<tr><td>(21.) HLL-Triple onset</td><td>(?<!.)3[J_=\+rlmnNpbkgtdszSZfvxhjw]{3}[a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]2[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]1[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^](?!.)</td></tr>
<tr><td></td><td></td></tr>
<tr><td>(22.) LHH-Coda+Coda</td><td>(?<!.)3[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]2[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^][J_=\+rlmnNpbkgtdszSZfvxhjw]1[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^][J_=\+rlmnNpbkgtdszSZfvxhjw](?!.)</td></tr>
<tr><td>(23.) LHH-Falling diphthong+Coda</td><td>(?<!.)3[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]2[J_=\+rlmnNpbkgtdszSZfvxhjw][BXW]1[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^][J_=\+rlmnNpbkgtdszSZfvxhjw](?!.)</td></tr>
<tr><td>(24.) LHH-Double onset+Coda</td><td>(?<!.)3[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]2[J_=\+rlmnNpbkgtdszSZfvxhjw]{2}[a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]1[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^][J_=\+rlmnNpbkgtdszSZfvxhjw](?!.)</td></tr>
<tr><td>(25.) LHH-Vowel length+Coda</td><td>(?<!.)3[J_=\+rlmnNpbkgtdszSZfvxhjw][&IUOE\/@Yaiuoe\)\|y]2[J_=\+rlmnNpbkgtdszSZfvxhjw][aiuoe\)\|y]1[J_=\+rlmnNpbkgtdszSZfvxhjw][&IUOE\/@Yaiuoe\)\|y][J_=\+rlmnNpbkgtdszSZfvxhjw](?!.)</td></tr>
<tr><td></td><td></td></tr>
<tr><td>(26.) LLLL</td><td>(?<!.)4[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]3[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]2[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]1[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^](?!.)</td></tr>
<tr><td>(27.) LHLL-Coda</td><td>(?<!.)4[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]3[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^][J_=\+rlmnNpbkgtdszSZfvxhjw]2[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]1[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^](?!.)</td></tr>
<tr><td>(28.) LLHL-Coda</td><td>(?<!.)4[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]3[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]2[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^][J_=\+rlmnNpbkgtdszSZfvxhjw]1[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^](?!.)</td></tr>
<tr><td>(29.) LLLH-Coda</td><td>(?<!.)4[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]3[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]2[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]1[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^][J_=\+rlmnNpbkgtdszSZfvxhjw](?!.)</td></tr>
<tr><td>(30.) LLLH-Double coda</td><td>(?<!.)4[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]3[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]2[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]1[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^][J_=\+rlmnNpbkgtdszSZfvxhjw]{2}(?!.)</td></tr>
<tr><td>(31.) LHLL-Falling diphthong</td><td>(?<!.)4[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]3[J_=\+rlmnNpbkgtdszSZfvxhjw][BXW]2[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]1[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^](?!.)</td></tr>
<tr><td>(32.) LLHL-Falling diphthong</td><td>(?<!.)4[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]3[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]2[J_=\+rlmnNpbkgtdszSZfvxhjw][BXW]1[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^](?!.)</td></tr>
<tr><td>(33.) LLLH-Falling diphthong</td><td>(?<!.)4[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]3[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]2[J_=\+rlmnNpbkgtdszSZfvxhjw][a&iIuUoOeE\)\|\/@yYc\$\{0qVA~#\^]1[J_=\+rlmnNpbkgtdszSZfvxhjw][BXW](?!.)</td></tr>
</table>

Appendix (17). Results of the linear mixed-effects regression analysis for *cánapa+patáta+maragiá* (all three items pooled together), for each acoustic parameter. For those parameters for which the pairwise comparison was performed, the results of the pairwise comparison are also reported.

Duration

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: Duration ~ Stress * Stress_position + Age + (1 | ID)
   Data: dataset

REML criterion at convergence: 7175.5

Scaled residuals:
    Min      1Q  Median      3Q     Max 
-3.2031 -0.6878 -0.1273  0.6088  4.1677 

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 108.7    10.43   
 Residual             729.1    27.00   
Number of obs: 759, groups:  ID, 30

Fixed effects:
                         Estimate Std. Error       df t value Pr(>|t|)    
(Intercept)               70.8674     5.5452  33.8686  12.780 1.64e-14 ***
Stressy                   56.2087     3.5054 723.6190  16.035  < 2e-16 ***
Stress_positionf           1.1824     2.9725 727.1660   0.398   0.6909    
Stress_positionp           1.0638     2.8961 727.4286   0.367   0.7135    
Age                        0.3361     0.1320  27.2084   2.547   0.0168 *  
Stressy:Stress_positionf -12.1512     5.1292 723.6190  -2.369   0.0181 *  
Stressy:Stress_positionp   7.7583     5.0004 723.6190   1.552   0.1212    
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1


> summary(pairwise)
$`simple contrasts for Stress`
Stress_position = a:
 contrast estimate   SE  df t.ratio p.value
 n - y       -56.2 3.51 724 -16.035  <.0001

Stress_position = f:
 contrast estimate   SE  df t.ratio p.value
 n - y       -44.1 3.74 724 -11.766  <.0001

Stress_position = p:
 contrast estimate   SE  df t.ratio p.value
 n - y       -64.0 3.57 724 -17.938  <.0001

Degrees-of-freedom method: kenward-roger 

$`simple contrasts for Stress_position`
Stress = n:
 contrast estimate   SE  df t.ratio p.value
 a - f      -1.182 2.97 728  -0.398  0.9165
 a - p      -1.064 2.90 728  -0.367  0.9284
 f - p       0.119 2.99 726   0.040  0.9991

Stress = y:
 contrast estimate   SE  df t.ratio p.value
 a - f      10.969 4.20 726   2.614  0.0247
 a - p      -8.822 4.09 726  -2.157  0.0794
 f - p     -19.791 4.23 725  -4.681  <.0001

Degrees-of-freedom method: kenward-roger 
P value adjustment: tukey method for comparing a family of 3 estimates
```

Duration (with z-scores)

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: Duration_z ~ Stress * Stress_position + Age + (1 | ID)
   Data: dataset

REML criterion at convergence: 1650.6

Scaled residuals:
```

```
    Min      1Q  Median      3Q     Max 
-3.2031 -0.6878 -0.1273  0.6088  4.1677 

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 0.07008  0.2647  
 Residual             0.46992  0.6855  
Number of obs: 759, groups:  ID, 30

Fixed effects:
                           Estimate Std. Error         df t value Pr(>|t|)    
(Intercept)               -0.791972   0.140782  33.868617  -5.626 2.67e-06 ***
Stressy                    1.427023   0.088995 723.618975  16.035  < 2e-16 ***
Stress_positionf           0.030019   0.075465 727.165962   0.398   0.6909    
Stress_positionp           0.027008   0.073526 727.428561   0.367   0.7135    
Age                        0.008534   0.003350  27.208441   2.547   0.0168 *  
Stressy:Stress_positionf  -0.308495   0.130219 723.618975  -2.369   0.0181 *  
Stressy:Stress_positionp   0.196966   0.126950 723.618975   1.552   0.1212    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Intensity

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: Intensity ~ Stress * Stress_position + (1 | ID)
   Data: dataset

REML criterion at convergence: 3873.5

Scaled residuals: 
    Min      1Q  Median      3Q     Max 
-4.2926 -0.5466  0.0835  0.6276  2.3098 

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 5.188    2.278   
 Residual             8.684    2.947   
Number of obs: 759, groups:  ID, 30

Fixed effects:
                         Estimate Std. Error       df t value Pr(>|t|)    
(Intercept)               74.5858     0.4709  41.5980 158.384  < 2e-16 ***
Stressy                    1.0420     0.3826 723.8892   2.724 0.006611 ** 
Stress_positionf           2.1888     0.3247 725.0980   6.741 3.22e-11 ***
Stress_positionp           0.1743     0.3164 725.3821   0.551 0.581896    
Stressy:Stress_positionf  -1.9152     0.5598 723.8892  -3.421 0.000658 ***
Stressy:Stress_positionp  -0.8057     0.5457 723.8892  -1.476 0.140290    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F0

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: f0 ~ Stress * Stress_position + Sex + Age + (1 | ID)
   Data: dataset

REML criterion at convergence: 7635.8

Scaled residuals: 
    Min      1Q  Median      3Q     Max 
-2.4342 -0.4525 -0.0547  0.3156  9.8476 

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  403     20.08   
 Residual             1817     42.63   
Number of obs: 737, groups:  ID, 30

Fixed effects:
                         Estimate Std. Error       df t value Pr(>|t|)    
(Intercept)              218.9703    10.2096  31.2976  21.448  < 2e-16 ***
Stressy                  -25.8916     5.5829 701.8733  -4.638 4.20e-06 ***
Stress_positionf         -23.9355     4.7288 704.8472  -5.062 5.31e-07 ***
Stress_positionp          -7.4176     4.6599 705.2209  -1.592   0.1119    
Sexm                     -52.6419     8.9148  26.9406  -5.905 2.74e-06 ***
Age                       -0.6329     0.2715  26.5767  -2.331   0.0276 *  
Stressy:Stress_positionf  46.6844     8.2565 702.3036   5.654 2.28e-08 ***
Stressy:Stress_positionp   0.7130     8.0082 702.0375   0.089   0.9291    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

```
> summary(pairwise)
$`simple contrasts for Stress`
Stress_position = a:
 contrast estimate   SE  df t.ratio p.value
 n - y        25.9 5.58 702   4.638  <.0001

Stress_position = f:
 contrast estimate   SE  df t.ratio p.value
 n - y       -20.8 6.08 703  -3.418  0.0007

Stress_position = p:
 contrast estimate   SE  df t.ratio p.value
 n - y        25.2 5.74 703   4.384  <.0001

Results are averaged over the levels of: Sex
Degrees-of-freedom method: kenward-roger

$`simple contrasts for Stress_position`
Stress = n:
 contrast estimate   SE  df t.ratio p.value
 a - f       23.94 4.73 705   5.061  <.0001
 a - p        7.42 4.66 705   1.592  0.2499
 f - p      -16.52 4.78 704  -3.455  0.0017

Stress = y:
 contrast estimate   SE  df t.ratio p.value
 a - f      -22.75 6.80 705  -3.345  0.0025
 a - p        6.70 6.54 704   1.026  0.5610
 f - p       29.45 6.88 703   4.282  0.0001

Results are averaged over the levels of: Sex
Degrees-of-freedom method: kenward-roger
P value adjustment: tukey method for comparing a family of 3 estimates
```

F1

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F1 ~ Stress + Stress_position + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 8940.5

Scaled residuals:
    Min      1Q  Median      3Q     Max
-5.2084 -0.4929 -0.0030  0.5353  5.2226

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 2746     52.40
 Residual             7308     85.49
Number of obs: 759, groups:  ID, 30

Fixed effects:
                 Estimate Std. Error       df t value Pr(>|t|)
(Intercept)       775.184     14.196   35.355  54.605  < 2e-16 ***
Stressy            71.908      6.583  725.895  10.924  < 2e-16 ***
Stress_positionf  -57.574      7.707  728.546  -7.471 2.29e-13 ***
Stress_positionp  -33.494      7.508  728.870  -4.461 9.44e-06 ***
Sexm             -110.256     20.329   27.917  -5.424 8.80e-06 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F2

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F2 ~ Stress * Stress_position + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 9631.6

Scaled residuals:
    Min      1Q  Median      3Q     Max
-4.8837 -0.5289  0.0635  0.5759  2.7654

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  4712     68.64
 Residual             18986    137.79
Number of obs: 759, groups:  ID, 30
```

```
Fixed effects:
                          Estimate Std. Error      df t value Pr(>|t|)
(Intercept)                1409.37      20.10   44.06  70.110  < 2e-16 ***
Stressy                      62.83      17.89  724.12   3.512 0.000472 ***
Stress_positionf            101.33      15.18  726.57   6.677 4.84e-11 ***
Stress_positionp            -21.41      14.79  726.78  -1.448 0.148168
Sexm                       -112.47      27.29   28.14  -4.122 0.000301 ***
Stressy:Stress_positionf   -110.67      26.17  724.12  -4.228 2.66e-05 ***
Stressy:Stress_positionp    -65.74      25.52  724.12  -2.576 0.010181 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1


> summary(pairwise)
$`simple contrasts for Stress`
Stress_position = a:
 contrast estimate   SE  df t.ratio p.value
 n - y      -62.83 17.9 724  -3.512  0.0005

Stress_position = f:
 contrast estimate   SE  df t.ratio p.value
 n - y       47.84 19.1 724   2.504  0.0125

Stress_position = p:
 contrast estimate   SE  df t.ratio p.value
 n - y        2.91 18.2 724   0.160  0.8729

Results are averaged over the levels of: Sex
Degrees-of-freedom method: kenward-roger

$`simple contrasts for Stress_position`
Stress = n:
 contrast estimate   SE  df t.ratio p.value
 a - f     -101.33 15.2 726  -6.677  <.0001
 a - p       21.41 14.8 727   1.447  0.3172
 f - p      122.74 15.3 726   8.031  <.0001

Stress = y:
 contrast estimate   SE  df t.ratio p.value
 a - f        9.34 21.4 725   0.436  0.9006
 a - p       87.15 20.9 725   4.175  0.0001
 f - p       77.81 21.6 725   3.606  0.0010

Results are averaged over the levels of: Sex
Degrees-of-freedom method: kenward-roger
P value adjustment: tukey method for comparing a family of 3 estimates
```

Spectral tilt

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: spectral_tilt_Praat ~ Stress + Stress_position + (1 | ID)
   Data: dataset

REML criterion at convergence: -7820.9

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.1581 -0.6384 -0.0323  0.6625  3.8516

Random effects:
 Groups   Name        Variance  Std.Dev.
 ID       (Intercept) 1.776e-06 0.001333
 Residual             1.585e-06 0.001259
Number of obs: 759, groups:  ID, 30

Fixed effects:
                   Estimate Std. Error         df t value Pr(>|t|)
(Intercept)      -8.025e-03  2.573e-04  3.350e+01 -31.190  < 2e-16 ***
Stressy          -3.085e-04  9.694e-05  7.258e+02  -3.182  0.00152 **
Stress_positionf  6.927e-04  1.136e-04  7.268e+02   6.099 1.73e-09 ***
Stress_positionp  6.694e-05  1.106e-04  7.271e+02   0.605  0.54537
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:
            (Intr) Strssy Strss_pstnf
Stressy     -0.126
Strss_pstnf -0.204  0.000
Strss_pstnp -0.209  0.000  0.481
```

Appendix (18). Results of the linear mixed-effects regression analysis for *cánapa,* for each acoustic parameter.

Duration

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: Duration ~ Stress + Age + (1 | ID)
   Data: dataset

REML criterion at convergence: 2535.7

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.9722 -0.7056 -0.1560  0.6403  3.0141

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  80.76    8.987
 Residual             747.61   27.342
Number of obs: 267, groups:  ID, 30

Fixed effects:
            Estimate Std. Error       df t value Pr(>|t|)
(Intercept)  70.3945     5.8826  30.1885  11.967 5.47e-13 ***
Stressy      56.2087     3.5497 235.7737  15.835  < 2e-16 ***
Age           0.3473     0.1445  27.5975   2.403   0.0232 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Intensity

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: Intensity ~ Stress + (1 | ID)
   Data: dataset

REML criterion at convergence: 1315.4

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.3422 -0.6155  0.0235  0.6065  2.2863

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 7.844    2.801
 Residual             6.138    2.478
Number of obs: 267, groups:  ID, 30

Fixed effects:
            Estimate Std. Error       df t value Pr(>|t|)
(Intercept)  74.6023     0.5441  31.3835  137.11  < 2e-16 ***
Stressy       1.0420     0.3216 236.0024    3.24  0.00137 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F0

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: f0 ~ Stress + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 2587.3

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.1191 -0.6071 -0.0282  0.4743  5.8378

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  785.9   28.03
 Residual             1006.9   31.73
Number of obs: 261, groups:  ID, 30

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
(Intercept)  203.208      7.410  29.854  27.423  < 2e-16 ***
```

```
Stressy      -25.302      4.157 230.015  -6.086 4.79e-09 ***
Sexm         -70.636     11.074  27.959  -6.379 6.69e-07 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F1

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F1 ~ Stress + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 3196.8

Scaled residuals:
    Min      1Q  Median      3Q     Max
-4.0525 -0.4237  0.0298  0.4855  4.5628

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 3539     59.49
 Residual             8563     92.53
Number of obs: 267, groups:  ID, 30

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
(Intercept)   777.49      16.78   31.60  46.327  < 2e-16 ***
Stressy        81.24      12.01  236.01   6.763 1.06e-10 ***
Sexm         -124.51      24.72   27.95  -5.037 2.52e-05 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F2

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F2 ~ Stress + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 3383.6

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.8782 -0.5317  0.0215  0.6531  2.9090

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  6744     82.12
 Residual             17477    132.20
Number of obs: 267, groups:  ID, 30

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
(Intercept)  1399.31      23.38   31.43  59.848  < 2e-16 ***
Stressy        62.83      17.16  235.68   3.661  0.00031 ***
Sexm          -89.88      34.38   27.62  -2.614  0.01431 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Spectral tilt

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: spectral_tilt_Praat ~ Stress + (1 | ID)
   Data: dataset

REML criterion at convergence: -2719.1

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.0387 -0.5719  0.1001  0.6220  2.8995

Random effects:
 Groups   Name        Variance  Std.Dev.
 ID       (Intercept) 2.055e-06 0.001433
 Residual             1.488e-06 0.001220
Number of obs: 267, groups:  ID, 30

Fixed effects:
              Estimate Std. Error         df t value Pr(>|t|)
(Intercept) -7.995e-03  2.773e-04  3.119e+01 -28.833   <2e-16 ***
Stressy     -3.962e-04  1.584e-04  2.360e+02  -2.502    0.013 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Appendix (19). Results of the linear mixed-effects regression analysis for *patáta,* for each acoustic parameter.

Duration

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: Duration ~ Stress + Age + (1 | ID)
   Data: dataset

REML criterion at convergence: 2412.1

Scaled residuals: 
    Min      1Q  Median      3Q     Max 
-2.7403 -0.6590 -0.1416  0.6346  3.6880 

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  99.03    9.951  
 Residual             631.20   25.124  
Number of obs: 258, groups:  ID, 29

Fixed effects:
            Estimate Std. Error       df t value Pr(>|t|)    
(Intercept)  72.7575     5.9590  28.4881  12.210  7.7e-13 ***
Stressy      63.9670     3.3180 227.5700  19.279  < 2e-16 ***
Age           0.3188     0.1481  26.3934   2.153   0.0406 *  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Intensity

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: Intensity ~ (1 | ID)
   Data: dataset

REML criterion at convergence: 1413.2

Scaled residuals: 
    Min      1Q  Median      3Q     Max 
-4.1095 -0.4907  0.1148  0.6629  1.7037 

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  4.315   2.077   
 Residual             11.975   3.460   
Number of obs: 258, groups:  ID, 29

Fixed effects:
            Estimate Std. Error     df t value Pr(>|t|)    
(Intercept)   74.752      0.442 28.125   169.1   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F0

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: f0 ~ Stress + Sex + Age + (1 | ID)
   Data: dataset

REML criterion at convergence: 2615.6

Scaled residuals: 
    Min      1Q  Median      3Q     Max 
-3.0435 -0.4650 -0.0300  0.3721  7.1720 

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  881.3   29.69   
 Residual             2031.5   45.07   
Number of obs: 248, groups:  ID, 29

Fixed effects:
            Estimate Std. Error       df t value Pr(>|t|)    
(Intercept) 222.3302    15.1597  25.1631  14.666 7.78e-14 ***
Stressy     -25.5362     6.0830 216.9555  -4.198 3.93e-05 ***
```

```
Sexm        -44.7508    13.8997  24.8501  -3.220  0.00356 **
Age          -1.0187     0.4182  24.6584  -2.436  0.02244 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F1

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F1 ~ Stress + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 2900.8

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.6820 -0.4739 -0.0013  0.5464  3.0912

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 2754     52.48
 Residual             3923     62.63
Number of obs: 258, groups:  ID, 29

Fixed effects:
            Estimate Std. Error       df t value Pr(>|t|)
(Intercept)  738.484     13.973   29.210  52.851  < 2e-16 ***
Stressy       75.176      8.272  228.103   9.088  < 2e-16 ***
Sexm        -110.681     21.328   27.145  -5.189  1.8e-05 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F2

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F2 ~ Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 3274.6

Scaled residuals:
    Min      1Q  Median      3Q     Max
-4.3156 -0.4266  0.0681  0.5446  2.5400

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  3411     58.4
 Residual             18265    135.1
Number of obs: 258, groups:  ID, 29

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
(Intercept)  1384.06      17.89   26.96  77.369  < 2e-16 ***
Sexm         -106.87      27.92   27.32  -3.828 0.000686 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Spectral tilt

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: spectral_tilt_Praat ~ Stress + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: -2687.6

Scaled residuals:
     Min       1Q   Median       3Q      Max
-2.96213 -0.63644 -0.07293  0.64999  2.35479

Random effects:
 Groups   Name        Variance  Std.Dev.
 ID       (Intercept) 1.637e-06 0.001280
 Residual             1.109e-06 0.001053
Number of obs: 258, groups:  ID, 29

Fixed effects:
              Estimate Std. Error         df t value Pr(>|t|)
(Intercept) -8.519e-03  3.251e-04  2.812e+01 -26.204  < 2e-16 ***
Stressy     -3.760e-04  1.391e-04  2.281e+02  -2.703  0.00739 **
Sexm         1.618e-03  5.007e-04  2.708e+01   3.232  0.00322 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Appendix (20). Results of the linear mixed-effects regression analysis for *maragiá,* for each acoustic parameter.

Duration

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: Duration ~ Stress + (1 | ID)
   Data: dataset

REML criterion at convergence: 2249.2

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.3680 -0.5467 -0.0792  0.5307  4.1476

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 200.4    14.16
 Residual             799.1    28.27
Number of obs: 234, groups:  ID, 30

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
(Intercept)   84.551      3.466  37.923   24.39   <2e-16 ***
Stressy       44.057      3.920 202.914   11.24   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Intensity

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: Intensity ~ Stress + (1 | ID)
   Data: dataset

REML criterion at convergence: 1136

Scaled residuals:
    Min      1Q  Median      3Q     Max
-4.3358 -0.5443  0.0632  0.6126  2.9279

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 4.968    2.229
 Residual             5.865    2.422
Number of obs: 234, groups:  ID, 30

Fixed effects:
            Estimate Std. Error       df t value Pr(>|t|)
(Intercept)  76.6916     0.4534  32.4573   169.1   <2e-16 ***
Stressy      -0.8732     0.3358 202.8385    -2.6     0.01 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F0

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: f0 ~ Stress + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 2365.1

Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.7985 -0.3380 -0.0043  0.2649  8.9829

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  303.2   17.41
 Residual             1835.8   42.85
Number of obs: 228, groups:  ID, 30

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
(Intercept)  172.521      6.051  36.055  28.511  < 2e-16 ***
Stressy       21.531      6.125 201.981   3.516 0.000542 ***
```

```
Sexm         -53.890      8.723  29.031  -6.178 9.74e-07 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F1

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F1 ~ Stress + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 2797.7

Scaled residuals:
    Min      1Q  Median      3Q     Max
-4.6876 -0.5546 -0.0334  0.6128  2.1218

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 2783     52.75
 Residual             8657     93.04
Number of obs: 234, groups:  ID, 30

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
(Intercept)   719.11      15.90   32.60  45.225  < 2e-16 ***
Stressy        57.66      12.90  203.65   4.469 1.31e-05 ***
Sexm         -103.48      23.20   27.90  -4.460 0.000122 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F2

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F2 ~ Stress + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 2986.4

Scaled residuals:
    Min      1Q  Median      3Q     Max
-5.7585 -0.5390  0.1224  0.5642  2.7524

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  5017     70.83
 Residual             19991    141.39
Number of obs: 234, groups:  ID, 30

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
(Intercept)  1526.83      22.35   32.81   68.31  < 2e-16 ***
Stressy       -47.84      19.61  203.30   -2.44   0.0156 *
Sexm         -149.67      32.39   27.34   -4.62 8.23e-05 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Spectral tilt

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: spectral_tilt_Praat ~ (1 | ID)
   Data: dataset

REML criterion at convergence: -2394.1

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.2325 -0.6594 -0.0433  0.6842  3.3066

Random effects:
 Groups   Name        Variance  Std.Dev.
 ID       (Intercept) 1.327e-06 0.001152
 Residual             1.535e-06 0.001239
Number of obs: 234, groups:  ID, 30

Fixed effects:
              Estimate Std. Error         df t value Pr(>|t|)
(Intercept) -0.0073654  0.0002268 28.3485646  -32.48   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Appendix (21). Results of the linear mixed-effects regression analysis for *càtaláno+càtamaráno* (the two items pooled together), for each acoustic parameter. For those parameters for which the pairwise comparison was performed, the results of the pairwise comparison are also reported. With respect to the name of the variables, the variable which in the text of the thesis is called *Sec_stress* is called *Vowel* in the R code reported in this appendix and the variable which in the text of the thesis is called *Interval* is called *Item* in the R code reported in this appendix.

Duration

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: Duration ~ Vowel + Item + Age + (1 | ID)
   Data: dataset

REML criterion at convergence: 2284.5

Scaled residuals: 
    Min      1Q  Median      3Q     Max 
-2.2830 -0.6920 -0.0543  0.5818  3.3855 

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  95.39    9.767  
 Residual             148.86   12.201  
Number of obs: 286, groups:  ID, 25

Fixed effects:
               Estimate Std. Error       df t value Pr(>|t|)    
(Intercept)     47.4831     5.0997  23.6592   9.311 2.22e-09 ***
Vowel2           7.7602     1.4429 258.4144   5.378 1.68e-07 ***
Itemcatamarano  -7.2084     1.4459 259.4351  -4.986 1.13e-06 ***
Age              0.3032     0.1383  22.1018   2.193   0.0391 *  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Intensity

```
summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: Intensity ~ Vowel + Item + (1 | ID)
   Data: dataset

REML criterion at convergence: 1387.4

Scaled residuals: 
    Min      1Q  Median      3Q     Max 
-4.7619 -0.4847  0.0817  0.5607  1.9460 

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 4.661    2.159   
 Residual             6.203    2.491   
Number of obs: 286, groups:  ID, 25

Fixed effects:
               Estimate Std. Error       df t value Pr(>|t|)    
(Intercept)     76.0081     0.5050  34.5779 150.521  < 2e-16 ***
Vowel2           0.7900     0.2945 258.9344   2.682  0.00778 ** 
Itemcatamarano  -0.8682     0.2952 259.9007  -2.941  0.00356 ** 
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F0

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: f0 ~ Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 2951

Scaled residuals: 
    Min      1Q  Median      3Q     Max 
```

```
-1.7333 -0.2086 -0.0074  0.1456  8.7864

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  443.6   21.06
 Residual             2356.2   48.54
Number of obs: 277, groups:  ID, 25

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
(Intercept)  185.304      6.336  21.013  29.248  < 2e-16 ***
Sexm         -57.929     10.942  22.965  -5.294 2.27e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

F0 (only females)

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: f0 ~ Vowel + Item + Age + (1 | ID)
   Data: dataset

REML criterion at convergence: 1559.6

Scaled residuals:
    Min      1Q  Median      3Q     Max
-5.9990 -0.3752  0.0105  0.4251  2.7397

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 184.9    13.60
 Residual             187.0    13.67
Number of obs: 190, groups:  ID, 16

Fixed effects:
               Estimate Std. Error       df t value Pr(>|t|)
(Intercept)    224.3914     9.2766  14.7292  24.189 2.88e-13 ***
Vowel2          -5.4214     1.9841 171.9895  -2.732 0.006945 **
Itemcatamarano   5.1977     1.9862 172.0188   2.617 0.009662 **
Age             -1.3818     0.2987  14.1934  -4.626 0.000379 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

F1

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F1 ~ Vowel + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 3261.7

Scaled residuals:
    Min      1Q  Median      3Q     Max
-6.0744 -0.4519  0.0600  0.4708  2.7322

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 4750     68.92
 Residual             4597     67.80
Number of obs: 286, groups:  ID, 25

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
(Intercept)  675.333     18.354  25.136  36.794  < 2e-16 ***
Vowel2        50.146      8.019 260.362   6.254 1.63e-09 ***
Sexm         -83.186     30.188  23.611  -2.756   0.0111 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

F2

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F2 ~ Vowel + (1 | ID)
   Data: dataset

REML criterion at convergence: 3695.9
```

```
Scaled residuals:
    Min      1Q  Median      3Q     Max 
-6.4010 -0.3030  0.0621  0.4261  3.5573 

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 18364    135.5   
 Residual             20742    144.0   
Number of obs: 286, groups:  ID, 25

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)    
(Intercept)  1496.64      29.79   28.88  50.242  < 2e-16 ***
Vowel2        -96.48      17.03  260.55  -5.664  3.9e-08 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Spectral tilt

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: spectral_tilt_Praat ~ Vowel * Item + (1 | ID)
   Data: dataset

REML criterion at convergence: -2984.7

Scaled residuals:
    Min      1Q  Median      3Q     Max 
-2.6455 -0.6287  0.0101  0.5829  3.4450 

Random effects:
 Groups   Name        Variance  Std.Dev. 
 ID       (Intercept) 1.314e-06 0.001146
 Residual             1.114e-06 0.001056
Number of obs: 286, groups:  ID, 25

Fixed effects:
                        Estimate Std. Error         df t value Pr(>|t|)    
(Intercept)           -7.829e-03  2.625e-04  3.317e+01 -29.820   <2e-16 ***
Vowel2                 2.837e-04  1.772e-04  2.568e+02   1.601   0.1105    
Itemcatamarano         3.362e-04  1.768e-04  2.572e+02   1.902   0.0583 .  
Vowel2:Itemcatamarano -5.876e-04  2.497e-04  2.568e+02  -2.353   0.0194 *  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> summary(pairwise)
$`simple contrasts for Vowel`
Item = catalano:
 contrast        estimate       SE  df t.ratio p.value
 Vowel1 - Vowel2 -0.000284 0.000177 258  -1.601  0.1105

Item = catamarano:
 contrast        estimate       SE  df t.ratio p.value
 Vowel1 - Vowel2  0.000304 0.000176 258   1.727  0.0853

Degrees-of-freedom method: kenward-roger 

$`simple contrasts for Item`
Vowel = 1:
 contrast                estimate       SE  df t.ratio p.value
 catalano - catamarano -0.000336 0.000177 258  -1.902  0.0583

Vowel = 2:
 contrast                estimate       SE  df t.ratio p.value
 catalano - catamarano  0.000251 0.000177 258   1.422  0.1563

Degrees-of-freedom method: kenward-roger
```

Appendix (22). Results of the linear mixed-effects regression analysis for *càtaláno,* for each acoustic parameter. With respect to the name of the variables, the variable which in the text of the thesis is called *Sec_stress* is called *Vowel* in the R code reported in this appendix.

Duration

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: Duration ~ Vowel + (1 | ID)
   Data: dataset

REML criterion at convergence: 1147.3

Scaled residuals:
     Min       1Q   Median       3Q      Max
-2.43855 -0.66858  0.00929  0.45368  2.99746

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 110.1    10.49
 Residual             151.9    12.32
Number of obs: 142, groups:  ID, 24

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
(Intercept)   56.093      2.594  30.750  21.621  < 2e-16 ***
Vowel2        10.534      2.068 115.782   5.093 1.38e-06 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Intensity

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: Intensity ~ Vowel + (1 | ID)
   Data: dataset

REML criterion at convergence: 729.3

Scaled residuals:
    Min      1Q  Median      3Q     Max
-4.0083 -0.4218  0.0480  0.6487  1.7061

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 4.525    2.127
 Residual             7.906    2.812
Number of obs: 142, groups:  ID, 24

Fixed effects:
            Estimate Std. Error       df t value Pr(>|t|)
(Intercept)  75.7726     0.5479  34.5377 138.304   <2e-16 ***
Vowel2        1.0889     0.4719 117.1823   2.307   0.0228 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F0

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: f0 ~ Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 1502.2

Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.4558 -0.2510 -0.0343  0.1510  7.3186

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  511.8   22.62
 Residual             3384.9   58.18
Number of obs: 137, groups:  ID, 24

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
```

```
(Intercept)  183.253      8.254  16.563  22.201 9.33e-14 ***
Sexm         -47.733     14.581  17.604  -3.274  0.00432 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F0 (only females)

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: f0 ~ Vowel + Age + (1 | ID)
   Data: dataset

REML criterion at convergence: 796.8

Scaled residuals:
    Min      1Q  Median      3Q     Max
-4.7026 -0.3152  0.0010  0.3513  2.5323

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 167.8    12.95
 Residual             239.6    15.48
Number of obs: 94, groups:  ID, 16

Fixed effects:
            Estimate Std. Error       df t value Pr(>|t|)
(Intercept) 224.2094     9.5854  15.5184  23.391  1.6e-13 ***
Vowel2       -7.9253     3.1931  76.9892  -2.482 0.015243 *
Age          -1.3274     0.3098  15.1586  -4.284 0.000637 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F1

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F1 ~ Vowel + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 1610

Scaled residuals:
    Min      1Q  Median      3Q     Max
-5.0322 -0.3989  0.0033  0.4531  3.0000

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 6203     78.76
 Residual             3989     63.16
Number of obs: 142, groups:  ID, 24

Fixed effects:
            Estimate Std. Error     df t value Pr(>|t|)
(Intercept)   673.78      21.38  24.93  31.507  < 2e-16 ***
Vowel2         40.30      10.60 117.06   3.802  0.00023 ***
Sexm          -79.20      35.95  22.14  -2.203  0.03830 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F2

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F2 ~ Vowel + (1 | ID)
   Data: dataset

REML criterion at convergence: 1858.2

Scaled residuals:
    Min      1Q  Median      3Q     Max
-5.4112 -0.2919  0.1021  0.4200  3.1242

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 16788    129.6
 Residual             24560    156.7
Number of obs: 142, groups:  ID, 24

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
(Intercept)  1489.26      32.35   32.87  46.041  < 2e-16 ***
Vowel2        -70.17      26.30  117.10  -2.668  0.00871 **
```

```
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Spectral tilt

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: spectral_tilt_Praat ~ (1 | ID)
   Data: dataset

REML criterion at convergence: -1484.3

Scaled residuals:
     Min       1Q   Median       3Q      Max
-2.45007 -0.63061 -0.03971  0.66224  2.27479

Random effects:
 Groups   Name        Variance  Std.Dev.
 ID       (Intercept) 1.353e-06 0.001163
 Residual             1.070e-06 0.001034
Number of obs: 142, groups:  ID, 24

Fixed effects:
              Estimate Std. Error         df t value Pr(>|t|)
(Intercept) -0.0076059  0.0002529 23.0480763  -30.07   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Appendix (23). Results of the linear mixed-effects regression analysis for *càtamaráno,* for each acoustic parameter. With respect to the name of the variables, the variable which in the text of the thesis is called *Sec_stress* is called *Vowel* in the R code reported in this appendix.

Duration

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: Duration ~ Vowel + Age + (1 | ID)
   Data: dataset

REML criterion at convergence: 1152.2

Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.7344 -0.7085  0.0263  0.5337  3.3963

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  93.02    9.645
 Residual             140.39   11.849
Number of obs: 144, groups:  ID, 25

Fixed effects:
            Estimate Std. Error       df t value Pr(>|t|)
(Intercept)  40.0219     5.2902  23.2761   7.565 1.02e-07 ***
Vowel2        5.0245     1.9748 117.1156   2.544   0.0123 *
Age           0.3498     0.1435  21.8677   2.438   0.0234 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Intensity

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: Intensity ~ (1 | ID)
   Data: dataset

REML criterion at convergence: 661.6

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.2491 -0.5567  0.0777  0.6221  2.1552

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 5.289    2.30
 Residual             4.039    2.01
Number of obs: 144, groups:  ID, 25

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
(Intercept)  75.5455     0.4907 23.8626     154   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F0

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: f0 ~ Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 1418.1

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.3360 -0.2222 -0.0021  0.1806  9.9745

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  354.5   18.83
 Residual             1380.5   37.15
Number of obs: 140, groups:  ID, 25

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
```

```
(Intercept)  187.670      6.045  21.507  31.047  < 2e-16 ***
Sexm         -67.095     10.425  24.014  -6.436 1.18e-06 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F0 (only females)

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: f0 ~ Age + (1 | ID)
   Data: dataset

REML criterion at convergence: 777.5

Scaled residuals:
    Min      1Q  Median      3Q     Max
-6.3720 -0.4136 -0.0064  0.3947  2.1006

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 194.7    13.95
 Residual             141.5    11.89
Number of obs: 96, groups:  ID, 16

Fixed effects:
            Estimate Std. Error       df t value Pr(>|t|)
(Intercept) 227.6807     9.5529  14.0000  23.834 9.86e-13 ***
Age          -1.4101     0.3105  14.0000  -4.542 0.000461 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F1

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F1 ~ Vowel + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 1634.1

Scaled residuals:
    Min      1Q  Median      3Q     Max
-4.3651 -0.4510  0.0592  0.5060  2.1968

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 4443     66.66
 Residual             4229     65.03
Number of obs: 144, groups:  ID, 25

Fixed effects:
            Estimate Std. Error     df t value Pr(>|t|)
(Intercept)   676.96      18.74  27.11  36.127  < 2e-16 ***
Vowel2         59.85      10.84 118.31   5.523 2.01e-07 ***
Sexm          -91.02      30.20  23.60  -3.014  0.00607 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F2

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F2 ~ Vowel + (1 | ID)
   Data: dataset

REML criterion at convergence: 1853.1

Scaled residuals:
    Min      1Q  Median      3Q     Max
-4.1648 -0.2908 -0.0110  0.4522  3.5136

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 18685    136.7
 Residual             18587    136.3
Number of obs: 144, groups:  ID, 25

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
(Intercept)  1504.96      31.79   31.89  47.342  < 2e-16 ***
Vowel2       -122.41      22.72  118.49  -5.387 3.69e-07 ***
---
```

```
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Spectral tilt

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: spectral_tilt_Praat ~ (1 | ID)
   Data: dataset

REML criterion at convergence: -1503.9

Scaled residuals: 
    Min      1Q  Median      3Q     Max 
-2.3157 -0.6015 -0.0263  0.5407  3.4562 

Random effects:
 Groups   Name        Variance  Std.Dev.
 ID       (Intercept) 1.237e-06 0.001112
 Residual             1.094e-06 0.001046
Number of obs: 144, groups:  ID, 25

Fixed effects:
              Estimate Std. Error         df t value Pr(>|t|)    
(Intercept) -0.0076448  0.0002395 22.8536261  -31.92   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Appendix (24). Results of the linear mixed-effects regression analysis for *Pápa+Pánama* (the two items pooled together), for each acoustic parameter. For those parameters for which the pairwise comparison was performed, the results of the pairwise comparison are also reported. With respect to the name of the variables, the variable which in the text of the thesis is called *Word_length* is called *Item* in the R code reported in this appendix.

Duration

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: Duration ~ Stress * Item + (1 | ID)
   Data: dataset

REML criterion at convergence: 2688.8

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.3313 -0.6611 -0.0179  0.5381  6.1532

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  42.51    6.52
 Residual             238.88   15.46
Number of obs: 322, groups:  ID, 25

Fixed effects:
                 Estimate Std. Error      df t value Pr(>|t|)
(Intercept)        87.714      1.980  51.202  44.294  < 2e-16 ***
Stressy            33.876      2.444 295.400  13.862  < 2e-16 ***
ItemPapa            8.975      2.350 306.680   3.819 0.000162 ***
Stressy:ItemPapa  -25.445      3.564 295.400  -7.140 7.29e-12 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> summary(pairwise)
$`simple contrasts for Stress`
Item = Panama:
 contrast estimate   SE  df t.ratio p.value
 n - y      -33.88 2.44 295 -13.862  <.0001

Item = Papa:
 contrast estimate   SE  df t.ratio p.value
 n - y       -8.43 2.59 295  -3.250  0.0013

Degrees-of-freedom method: kenward-roger

$`simple contrasts for Item`
Stress = n:
 contrast      estimate   SE  df t.ratio p.value
 Panama - Papa    -8.97 2.35 306  -3.813  0.0002

Stress = y:
 contrast      estimate   SE  df t.ratio p.value
 Panama - Papa    16.47 2.74 304   6.002  <.0001

Degrees-of-freedom method: kenward-roger
```

Intensity

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: intensity ~ Stress + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 1644.3

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.7116 -0.6293  0.0825  0.6590  2.7642

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 7.932    2.816
 Residual             8.087    2.844
Number of obs: 322, groups:  ID, 25
```

```
Fixed effects:
            Estimate Std. Error       df t value Pr(>|t|)    
(Intercept)  70.2355     0.6766  24.2445 103.814   <2e-16 ***
Stressy      -4.4842     0.3230 295.5372 -13.883   <2e-16 ***
Sexm          3.5579     1.4606  21.2744   2.436   0.0237 *  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F0

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: f0 ~ Stress + Item + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 3135.5

Scaled residuals: 
    Min      1Q  Median      3Q     Max 
-2.6730 -0.4944 -0.0161  0.4932  7.9974 

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  585.8   24.20   
 Residual             1068.6   32.69   
Number of obs: 317, groups:  ID, 25

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)    
(Intercept)  182.061      6.354  30.568  28.651  < 2e-16 ***
Stressy       48.982      3.788 290.682  12.931  < 2e-16 ***
ItemPapa      14.913      3.905 301.767   3.819 0.000163 ***
Sexm         -81.742     12.944  22.011  -6.315 2.35e-06 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F1

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F1 ~ Stress + Item + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 4057.2

Scaled residuals: 
    Min      1Q  Median      3Q     Max 
-4.4684 -0.5520  0.0889  0.5408  3.3403 

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  5356     73.18  
 Residual             17159    130.99  
Number of obs: 322, groups:  ID, 25

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)    
(Intercept)   859.77      20.90   34.52  41.129  < 2e-16 ***
Stressy       213.20      15.08  296.03  14.142  < 2e-16 ***
ItemPapa      -50.16      15.44  310.28  -3.249  0.00129 ** 
Sexm         -246.89      40.67   21.58  -6.070 4.49e-06 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F2

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F2 ~ Stress + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 4080.2

Scaled residuals: 
    Min      1Q  Median      3Q     Max 
-4.7412 -0.5194  0.1043  0.5663  3.7831 

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  8658     93.05  
 Residual             17494    132.26  
Number of obs: 322, groups:  ID, 25
```

```
Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)    
(Intercept)  1432.05      23.69   27.82  60.459  < 2e-16 ***
Stressy       145.68      15.02  297.60   9.699  < 2e-16 ***
Sexm         -229.16      49.86   22.44  -4.596 0.000135 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Spectral tilt

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: spectral_tilt_Praat ~ Stress * Item + Sex + Age + (1 | ID)
   Data: dataset

REML criterion at convergence: -3281.8

Scaled residuals: 
     Min       1Q   Median       3Q      Max 
-2.43621 -0.73510 -0.01005  0.64177  2.53614 

Random effects:
 Groups   Name        Variance  Std.Dev.
 ID       (Intercept) 1.228e-06 0.001108
 Residual             1.384e-06 0.001177
Number of obs: 322, groups:  ID, 25

Fixed effects:
                   Estimate Std. Error         df t value Pr(>|t|)    
(Intercept)      -4.719e-03  1.023e-03  2.197e+01  -4.614 0.000135 ***
Stressy           1.382e-03  1.860e-04  2.947e+02   7.427 1.21e-12 ***
ItemPapa         -1.339e-03  1.808e-04  2.998e+02  -7.407 1.32e-12 ***
Sexm             -1.325e-03  5.844e-04  2.152e+01  -2.267 0.033819 *  
Age              -1.007e-04  3.590e-05  2.137e+01  -2.806 0.010465 *  
Stressy:ItemPapa  8.272e-04  2.713e-04  2.947e+02   3.049 0.002504 ** 
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1


> summary(pairwise)
$`simple contrasts for Stress`
Item = Panama:
 contrast estimate       SE  df t.ratio p.value
 n - y    -0.00138 0.000186 294  -7.427  <.0001

Item = Papa:
 contrast estimate       SE  df t.ratio p.value
 n - y    -0.00221 0.000197 294 -11.185  <.0001

Results are averaged over the levels of: Sex 
Degrees-of-freedom method: kenward-roger 

$`simple contrasts for Item`
Stress = n:
 contrast      estimate       SE  df t.ratio p.value
 Panama - Papa 0.001339 0.000181 299   7.401  <.0001

Stress = y:
 contrast      estimate       SE  df t.ratio p.value
 Panama - Papa 0.000512 0.000210 298   2.434  0.0155

Results are averaged over the levels of: Sex 
Degrees-of-freedom method: kenward-roger
```

Appendix (25). Results of the linear mixed-effects regression analysis for *Pápa,* for each acoustic parameter.

Duration

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: Duration ~ Stress + (1 | ID)
   Data: dataset

REML criterion at convergence: 1174.7

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.4585 -0.5004 -0.0113  0.4015  6.1372

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  82.56    9.086
 Residual             197.30   14.046
Number of obs: 142, groups:  ID, 25

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
(Intercept)   96.788      2.475  39.142  39.114  < 2e-16 ***
Stressy        8.431      2.358 116.110   3.576 0.000509 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Intensity

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: intensity ~ Stress + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 732.4

Scaled residuals:
     Min       1Q   Median       3Q      Max
-2.36894 -0.66287  0.00157  0.74730  2.26181

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 9.357    3.059
 Residual             7.409    2.722
Number of obs: 142, groups:  ID, 25

Fixed effects:
            Estimate Std. Error       df t value Pr(>|t|)
(Intercept)  70.2005     0.7680  27.0192  91.408  < 2e-16 ***
Stressy      -4.2710     0.4568 115.4315  -9.349 8.28e-16 ***
Sexm          3.6277     1.6297  22.0013   2.226   0.0366 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

F0

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: f0 ~ Stress + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 1344.1

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.2837 -0.5158 -0.0208  0.3268  3.6215

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 864.0    29.39
 Residual             694.3    26.35
Number of obs: 140, groups:  ID, 25

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
```

```
(Intercept)  200.959      7.397  27.945  27.169  < 2e-16 ***
Stressy       46.165      4.459 114.288  10.352  < 2e-16 ***
Sexm         -92.696     15.732  23.001  -5.892 5.26e-06 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F1

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F1 ~ Stress + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 1736.8

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.6859 -0.5504  0.1034  0.4692  2.2922

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  6245     79.02
 Residual             11403    106.78
Number of obs: 142, groups:  ID, 25

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
(Intercept)   797.97      22.33   33.22  35.737  < 2e-16 ***
Stressy       230.22      17.92  116.65  12.845  < 2e-16 ***
Sexm         -233.23      45.25   22.83  -5.154 3.25e-05 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F2

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F2 ~ Stress + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 1796.4

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.8524 -0.4852  0.0297  0.4968  3.3370

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  7803     88.34
 Residual             18003    134.17
Number of obs: 142, groups:  ID, 25

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
(Intercept)  1432.18      26.15   35.45  54.773  < 2e-16 ***
Stressy       144.29      22.52  116.93   6.407 3.23e-09 ***
Sexm         -246.69      52.13   23.00  -4.732 9.08e-05 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Spectral tilt

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: spectral_tilt_Praat ~ Stress + (1 | ID)
   Data: dataset

REML criterion at convergence: -1445.1

Scaled residuals:
     Min       1Q   Median       3Q      Max
-2.48816 -0.56047 -0.02238  0.70296  2.48467

Random effects:
 Groups   Name        Variance  Std.Dev.
 ID       (Intercept) 1.919e-06 0.001385
 Residual             1.227e-06 0.001108
Number of obs: 142, groups:  ID, 25

Fixed effects:
              Estimate Std. Error         df t value Pr(>|t|)
(Intercept) -9.015e-03  3.073e-04  2.910e+01  -29.33   <2e-16 ***
Stressy      2.209e-03  1.859e-04  1.161e+02   11.88   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Appendix (26). Results of the linear mixed-effects regression analysis for *Pánama,* for each acoustic parameter.

Duration

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: Duration ~ Stress + (1 | ID)
   Data: dataset

REML criterion at convergence: 1506.6

Scaled residuals:
     Min       1Q   Median       3Q      Max
-1.93182 -0.62658 -0.07675  0.60154  2.73131

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  49.36    7.025
 Residual             235.82   15.356
Number of obs: 180, groups:  ID, 20

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
(Intercept)   88.434      2.105  26.067   42.00   <2e-16 ***
Stressy       33.876      2.428 159.000   13.95   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Intensity

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: intensity ~ Stress + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 921.9

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.0526 -0.6890  0.1279  0.6686  2.1035

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 7.415    2.723
 Residual             7.945    2.819
Number of obs: 180, groups:  ID, 20

Fixed effects:
            Estimate Std. Error       df t value Pr(>|t|)
(Intercept)  69.7706     0.7584  19.4614  91.992   <2e-16 ***
Stressy      -4.7303     0.4457 159.0000 -10.614   <2e-16 ***
Sexm          4.0105     1.4875  18.0000   2.696   0.0148 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

F0

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: f0 ~ Stress + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 1771.7

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.2893 -0.5352 -0.0120  0.5342  6.9032

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  508.2   22.54
 Residual             1229.2   35.06
Number of obs: 177, groups:  ID, 20

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
(Intercept)  180.878      6.815  20.887  26.543  < 2e-16 ***
```

```
Stressy       51.226      5.576 156.353   9.187 2.35e-16 ***
Sexm         -75.322     13.209  18.402  -5.702 1.92e-05 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F1

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F1 ~ Stress + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 2288.3

Scaled residuals: 
    Min      1Q  Median      3Q     Max 
-4.0008 -0.4280  0.0763  0.5437  2.9128 

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  7318     85.55  
 Residual             19326    139.02  
Number of obs: 180, groups:  ID, 20

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)    
(Intercept)   871.08      26.17   21.18  33.289  < 2e-16 ***
Stressy       198.11      21.98  159.00   9.013 6.06e-16 ***
Sexm         -260.20      50.24   18.00  -5.179 6.31e-05 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F2

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F2 ~ Stress + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 2280.4

Scaled residuals: 
    Min      1Q  Median      3Q     Max 
-4.3741 -0.4604  0.1305  0.5608  2.9047 

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  9313     96.5   
 Residual             18029    134.3   
Number of obs: 180, groups:  ID, 20

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)    
(Intercept)  1440.66      28.36   20.46  50.793  < 2e-16 ***
Stressy       149.48      21.23  159.00   7.041 5.42e-11 ***
Sexm         -226.97      54.93   18.00  -4.132 0.000626 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Spectral tilt

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: spectral_tilt_Praat ~ Stress + Sex + Age + (1 | ID)
   Data: dataset

REML criterion at convergence: -1826.3

Scaled residuals: 
     Min       1Q   Median       3Q      Max 
-2.11505 -0.74672 -0.03409  0.61022  2.21944 

Random effects:
 Groups   Name        Variance  Std.Dev.
 ID       (Intercept) 1.283e-06 0.001133
 Residual             1.293e-06 0.001137
Number of obs: 180, groups:  ID, 20

Fixed effects:
              Estimate Std. Error         df t value Pr(>|t|)    
(Intercept) -4.346e-03  1.102e-03  1.710e+01  -3.945  0.00103 ** 
Stressy      1.382e-03  1.798e-04  1.590e+02   7.684 1.49e-12 ***
Sexm        -1.462e-03  6.267e-04  1.700e+01  -2.332  0.03224 *  
Age         -1.145e-04  3.808e-05  1.700e+01  -3.007  0.00793 ** 
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Appendix (27). Results of the linear mixed-effects regression analysis for *Fànatísmus+kàtalysíeren* (the two items pooled together), for each acoustic parameter. For those parameters for which the pairwise comparison was performed, the results of the pairwise comparison are also reported. With respect to the name of the variables, the variable which in the text of the thesis is called *Sec_stress* is called *Vowel* in the R code reported in this appendix and the variable which in the text of the thesis is called *Interval* is called *Item* in the R code reported in this appendix.

Duration

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: Duration ~ Vowel * Item + (1 | ID)
   Data: dataset

REML criterion at convergence: 2920.6

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.3827 -0.6335 -0.0221  0.5366  3.9080

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  97.68    9.884
 Residual             180.75   13.444
Number of obs: 358, groups:  ID, 30

Fixed effects:
                        Estimate Std. Error      df t value Pr(>|t|)
(Intercept)               54.749      2.300  56.581  23.806  < 2e-16 ***
Vowel2                    17.088      2.015 325.050   8.479  8.1e-16 ***
ItemKatalysieren          49.259      2.010 325.104  24.504  < 2e-16 ***
Vowel2:ItemKatalysieren  -30.855      2.842 325.050 -10.856  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> summary(pairwise)
$`simple contrasts for Vowel`
Item = Fanatismus:
 contrast        estimate   SE  df t.ratio p.value
 Vowel1 - Vowel2    -17.1 2.02 325  -8.479  <.0001

Item = Katalysieren:
 contrast        estimate   SE  df t.ratio p.value
 Vowel1 - Vowel2     13.8 2.00 325   6.870  <.0001

Degrees-of-freedom method: kenward-roger

$`simple contrasts for Item`
Vowel = 1:
 contrast                  estimate   SE  df t.ratio p.value
 Fanatismus - Katalysieren    -49.3 2.01 325 -24.504  <.0001

Vowel = 2:
 contrast                  estimate   SE  df t.ratio p.value
 Fanatismus - Katalysieren    -18.4 2.01 325  -9.155  <.0001

Degrees-of-freedom method: kenward-roger
```

Intensity

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: intensity ~ Vowel * Item + (1 | ID)
   Data: dataset

REML criterion at convergence: 1701.8

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.3571 -0.5350  0.0420  0.5546  2.8503

Random effects:
 Groups   Name        Variance Std.Dev.
```

```
 ID       (Intercept) 19.737   4.443
 Residual              4.957   2.226
Number of obs: 358, groups:  ID, 30

Fixed effects:
                         Estimate Std. Error        df t value Pr(>|t|)
(Intercept)              72.95105    0.84479  32.72525  86.354  < 2e-16 ***
Vowel2                   -0.02772    0.33375 325.00629  -0.083    0.934
ItemKatalysieren         -8.18109    0.33291 325.01487 -24.574  < 2e-16 ***
Vowel2:ItemKatalysieren   3.62041    0.47068 325.00629   7.692 1.75e-13 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> summary(pairwise)
$`simple contrasts for Vowel`
Item = Fanatismus:
 contrast        estimate    SE  df t.ratio p.value
 Vowel1 - Vowel2   0.0277 0.334 325   0.083  0.9339

Item = Katalysieren:
 contrast        estimate    SE  df t.ratio p.value
 Vowel1 - Vowel2  -3.5927 0.332 325 -10.825  <.0001

Degrees-of-freedom method: kenward-roger

$`simple contrasts for Item`
Vowel = 1:
 contrast                  estimate    SE  df t.ratio p.value
 Fanatismus - Katalysieren     8.18 0.333 325  24.574  <.0001

Vowel = 2:
 contrast                  estimate    SE  df t.ratio p.value
 Fanatismus - Katalysieren     4.56 0.333 325  13.699  <.0001

Degrees-of-freedom method: kenward-roger
```

F0

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: f0 ~ Vowel + Item + Sex + Region + (1 | ID)
   Data: dataset

REML criterion at convergence: 3005

Scaled residuals:
    Min      1Q  Median      3Q     Max
-7.2835 -0.3616 -0.0371  0.3563  6.0982

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 445.6    21.11
 Residual             268.7    16.39
Number of obs: 355, groups:  ID, 30

Fixed effects:
                             Estimate Std. Error       df t value Pr(>|t|)
(Intercept)                   209.548      9.083   21.869  23.069  < 2e-16 ***
Vowel2                         -9.241      1.741  323.053  -5.307 2.07e-07 ***
ItemKatalysieren               12.167      1.742  323.085   6.984 1.64e-11 ***
Sexm                         -112.498     10.080   21.037 -11.161 2.68e-10 ***
RegionBayern                   29.235     13.108   21.013   2.230   0.0368 *
RegionHessen                    3.065     12.100   21.017   0.253   0.8025
RegionMecklenburg-Vorpommern  -24.280     23.430   20.994  -1.036   0.3118
RegionNiedersachsen            16.440     14.003   21.063   1.174   0.2535
RegionNordrhein-Westfalen       1.044     13.112   21.034   0.080   0.9373
RegionSachsen                 -56.046     23.430   20.994  -2.392   0.0262 *
RegionSachsen-Anhalt           33.783     24.832   20.995   1.360   0.1881
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> summary(pairwise)
$`simple contrasts for Vowel`
Item = Fanatismus:
 contrast        estimate   SE  df t.ratio p.value
 Vowel1 - Vowel2     9.24 1.74 323   5.307  <.0001

Item = Katalysieren:
 contrast        estimate   SE  df t.ratio p.value
 Vowel1 - Vowel2     9.24 1.74 323   5.307  <.0001

Results are averaged over the levels of: Sex, Region
Degrees-of-freedom method: kenward-roger

$`simple contrasts for Item`
Vowel = 1:
```

```
 contrast                  estimate   SE  df t.ratio p.value
 Fanatismus - Katalysieren    -12.2 1.74 323  -6.984  <.0001

Vowel = 2:
 contrast                  estimate   SE  df t.ratio p.value
 Fanatismus - Katalysieren    -12.2 1.74 323  -6.984  <.0001

Results are averaged over the levels of: Sex, Region
Degrees-of-freedom method: kenward-roger
```

F1

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F1 ~ Vowel * Item + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 4612.5

Scaled residuals:
    Min      1Q  Median      3Q     Max
-4.8084 -0.4033 -0.0026  0.4428  6.9577

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  7015     83.76
 Residual             23028    151.75
Number of obs: 358, groups:  ID, 30

Fixed effects:
                        Estimate Std. Error      df t value Pr(>|t|)
(Intercept)               792.64      24.17   61.88  32.800  < 2e-16 ***
Vowel2                    -19.49      22.75  325.07  -0.857  0.39211
ItemKatalysieren          160.85      22.69  325.15   7.089 8.45e-12 ***
Sexm                     -144.88      40.81   28.02  -3.550  0.00138 **
Vowel2:ItemKatalysieren  -344.43      32.08  325.07 -10.736  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> summary(pairwise)
$`simple contrasts for Vowel`
Item = Fanatismus:
 contrast        estimate   SE  df t.ratio p.value
 Vowel1 - Vowel2     19.5 22.7 325   0.857  0.3921

Item = Katalysieren:
 contrast        estimate   SE  df t.ratio p.value
 Vowel1 - Vowel2    363.9 22.6 325  16.088  <.0001

Results are averaged over the levels of: Sex
Degrees-of-freedom method: kenward-roger

$`simple contrasts for Item`
Vowel = 1:
 contrast                  estimate   SE  df t.ratio p.value
 Fanatismus - Katalysieren     -161 22.7 325  -7.089  <.0001

Vowel = 2:
 contrast                  estimate   SE  df t.ratio p.value
 Fanatismus - Katalysieren      184 22.7 325   8.091  <.0001

Results are averaged over the levels of: Sex
Degrees-of-freedom method: kenward-roger
```

F2

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F2 ~ Vowel * Item + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 4637.5

Scaled residuals:
    Min      1Q  Median      3Q     Max
-4.0479 -0.3911  0.1233  0.5702  5.6863

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  9788     98.93
 Residual             24278    155.82
Number of obs: 358, groups:  ID, 30

Fixed effects:
```

```
                        Estimate Std. Error      df t value Pr(>|t|)
(Intercept)              1423.28      26.83   54.20  53.054  < 2e-16 ***
Vowel2                    111.32      23.36  325.05   4.766 2.84e-06 ***
ItemKatalysieren          362.11      23.30  325.12  15.543  < 2e-16 ***
Sexm                     -193.70      46.92   28.01  -4.128 0.000298 ***
Vowel2:ItemKatalysieren  -218.00      32.94  325.05  -6.618 1.50e-10 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> summary(pairwise)
$`simple contrasts for Vowel`
Item = Fanatismus:
 contrast        estimate   SE  df t.ratio p.value
 Vowel1 - Vowel2     -111 23.4 325  -4.766  <.0001

Item = Katalysieren:
 contrast        estimate   SE  df t.ratio p.value
 Vowel1 - Vowel2      107 23.2 325   4.593  <.0001

Results are averaged over the levels of: Sex
Degrees-of-freedom method: kenward-roger

$`simple contrasts for Item`
Vowel = 1:
 contrast                  estimate   SE  df t.ratio p.value
 Fanatismus - Katalysieren     -362 23.3 325 -15.543  <.0001

Vowel = 2:
 contrast                  estimate   SE  df t.ratio p.value
 Fanatismus - Katalysieren     -144 23.3 325  -6.186  <.0001

Results are averaged over the levels of: Sex
Degrees-of-freedom method: kenward-roger
```

Spectral tilt

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: spectral_tilt_Praat ~ Vowel * Item + (1 | ID)
   Data: dataset

REML criterion at convergence: -3631.2

Scaled residuals:
     Min       1Q   Median       3Q      Max
-2.88880 -0.58758  0.02621  0.55015  2.74370

Random effects:
 Groups   Name        Variance  Std.Dev.
 ID       (Intercept) 1.473e-06 0.001214
 Residual             1.543e-06 0.001242
Number of obs: 357, groups:  ID, 30

Fixed effects:
                          Estimate Std. Error         df t value Pr(>|t|)
(Intercept)             -7.433e-03  2.578e-04  4.463e+01 -28.834  < 2e-16 ***
Vowel2                   1.556e-03  1.862e-04  3.240e+02   8.356 1.94e-15 ***
ItemKatalysieren         1.205e-03  1.857e-04  3.240e+02   6.487 3.27e-10 ***
Vowel2:ItemKatalysieren  8.796e-04  2.630e-04  3.240e+02   3.345  0.00092 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> summary(pairwise)
$`simple contrasts for Vowel`
Item = Fanatismus:
 contrast        estimate       SE  df t.ratio p.value
 Vowel1 - Vowel2 -0.00156 0.000186 324  -8.356  <.0001

Item = Katalysieren:
 contrast        estimate       SE  df t.ratio p.value
 Vowel1 - Vowel2 -0.00244 0.000186 324 -13.113  <.0001

Degrees-of-freedom method: kenward-roger

$`simple contrasts for Item`
Vowel = 1:
 contrast                  estimate       SE  df t.ratio p.value
 Fanatismus - Katalysieren -0.00120 0.000186 324  -6.487  <.0001

Vowel = 2:
 contrast                  estimate       SE  df t.ratio p.value
 Fanatismus - Katalysieren -0.00208 0.000186 324 -11.189  <.0001

Degrees-of-freedom method: kenward-roger
```

Appendix (28). Results of the linear mixed-effects regression analysis for *Fànatísmus,* for each acoustic parameter. With respect to the name of the variables, the variable which in the text of the thesis is called *Sec_stress* is called *Vowel* in the R code reported in this appendix.

Duration

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: Duration ~ Vowel + (1 | ID)
   Data: dataset

REML criterion at convergence: 1405.7

Scaled residuals: 
    Min      1Q  Median      3Q     Max 
-2.2622 -0.5989  0.0471  0.5380  3.7743 

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  87.92    9.377  
 Residual             124.90   11.176  
Number of obs: 178, groups:  ID, 30

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)    
(Intercept)   54.866      2.083  40.817   26.35   <2e-16 ***
Vowel2        17.088      1.675 146.894   10.20   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Intensity

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: intensity ~ (1 | ID)
   Data: dataset

REML criterion at convergence: 854.7

Scaled residuals: 
    Min      1Q  Median      3Q     Max 
-2.1989 -0.4664 -0.0277  0.5213  4.2953 

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 24.651   4.965   
 Residual              3.914   1.978   
Number of obs: 178, groups:  ID, 30

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)    
(Intercept)  72.9560     0.9186 29.0241   79.42   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F0

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: f0 ~ Vowel + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 1510.8

Scaled residuals: 
    Min      1Q  Median      3Q     Max 
-5.4619 -0.2680  0.0509  0.2677  4.2989 

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 683.7    26.15   
 Residual             185.7    13.63   
Number of obs: 178, groups:  ID, 30

Fixed effects:
            Estimate Std. Error       df t value Pr(>|t|)    
```

```
(Intercept)  215.184      5.669   29.940  37.956  < 2e-16 ***
Vowel2       -12.285      2.043  147.025  -6.014 1.37e-08 ***
Sexm        -102.166     11.541   27.996  -8.853 1.32e-09 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F0 (only females)

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F1 ~ +(1 | ID)
   Data: dataset

REML criterion at convergence: 1616.7

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.9069 -0.5513 -0.0696  0.5494  3.4774

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 8289     91.04
 Residual             6293     79.33
Number of obs: 136, groups:  ID, 23

Fixed effects:
            Estimate Std. Error     df t value Pr(>|t|)
(Intercept)   786.33      20.17  22.08   38.98   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F1

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F1 ~ Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 2083.3

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.2103 -0.5352 -0.0192  0.4978  3.8434

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 9030     95.03
 Residual             5249     72.45
Number of obs: 178, groups:  ID, 30

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
(Intercept)   786.35      20.77   28.09   37.86  < 2e-16 ***
Sexm         -158.98      42.97   28.01   -3.70 0.000934 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F2

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F2 ~ Vowel + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 2287.6

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.4411 -0.2932  0.0989  0.4740  3.0358

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 10794    103.9
 Residual             20695    143.9
Number of obs: 178, groups:  ID, 30

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
(Intercept)  1415.08      27.17   39.25  52.074  < 2e-16 ***
Vowel2        111.32      21.57  147.02   5.162  7.8e-07 ***
Sexm         -164.34      51.54   27.87  -3.188  0.00352 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Spectral tilt

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: spectral_tilt_Praat ~ Vowel + (1 | ID)
   Data: dataset

REML criterion at convergence: -1820.9

Scaled residuals:
     Min       1Q   Median       3Q      Max
-2.42970 -0.66063  0.06793  0.61139  2.48532

Random effects:
 Groups   Name        Variance  Std.Dev.
 ID       (Intercept) 2.106e-06 0.001451
 Residual             1.196e-06 0.001094
Number of obs: 178, groups:  ID, 30

Fixed effects:
              Estimate Std. Error         df t value Pr(>|t|)
(Intercept) -7.426e-03  2.892e-04  3.431e+01 -25.674   <2e-16 ***
Vowel2       1.556e-03  1.639e-04  1.471e+02   9.489   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Appendix (29). Results of the linear mixed-effects regression analysis for *kàtalysíeren,* for each acoustic parameter. With respect to the name of the variables, the variable which in the text of the thesis is called *Sec_stress* is called *Vowel* in the R code reported in this appendix.

Duration

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: Duration ~ Vowel + Region + (1 | ID)
   Data: dataset

REML criterion at convergence: 1426.9

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.9062 -0.5406 -0.0449  0.5050  3.5332

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 119.4    10.93
 Residual             170.7    13.06
Number of obs: 180, groups:  ID, 30

Fixed effects:
                             Estimate Std. Error      df t value Pr(>|t|)
(Intercept)                    98.365      5.058  23.721  19.447 4.42e-16 ***
Vowel2                        -13.768      1.947 149.000  -7.070 5.59e-11 ***
RegionBayern                   10.372      7.362  22.000   1.409   0.1729
RegionHessen                    9.357      6.764  22.000   1.383   0.1805
RegionMecklenburg-Vorpommern   -4.083     13.132  22.000  -0.311   0.7588
RegionNiedersachsen            15.209      7.848  22.000   1.938   0.0656 .
RegionNordrhein-Westfalen      -9.036      7.362  22.000  -1.227   0.2327
RegionSachsen                   7.833     13.132  22.000   0.596   0.5570
RegionSachsen-Anhalt           32.538     13.132  22.000   2.478   0.0214 *
```

Intensity

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: intensity ~ Vowel + (1 | ID)
   Data: dataset

REML criterion at convergence: 857.7

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.1744 -0.6194  0.0092  0.6395  2.4175

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 16.73    4.091
 Residual              4.06    2.015
Number of obs: 180, groups:  ID, 30

Fixed effects:
            Estimate Std. Error       df t value Pr(>|t|)
(Intercept)  64.7700     0.7765  31.2890   83.42   <2e-16 ***
Vowel2        3.5927     0.3004 149.0000   11.96   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

F0

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: f0 ~ Vowel + Sex + Age + Region + (1 | ID)
   Data: dataset

REML criterion at convergence: 1509.4

Scaled residuals:
    Min      1Q  Median      3Q     Max
-5.8735 -0.3074  0.0117  0.3490  5.0124

Random effects:
 Groups   Name        Variance Std.Dev.
```

```
 ID       (Intercept) 321.7    17.94
 Residual             328.6    18.13
Number of obs: 177, groups:  ID, 30

Fixed effects:
                              Estimate Std. Error        df t value Pr(>|t|)
(Intercept)                   252.7365    17.8042   20.1696  14.195 5.81e-12 ***
Vowel2                         -6.1189     2.7332  146.3067  -2.239  0.02669 *
Sexm                         -121.3036     9.2859   20.2713 -13.063 2.47e-11 ***
Age                            -1.4543     0.6784   19.9360  -2.144  0.04457 *
RegionBayern                   33.7371    11.8068   19.9151   2.857  0.00976 **
RegionHessen                   15.0235    11.6418   19.9253   1.290  0.21166
RegionMecklenburg-Vorpommern  -19.1962    21.0904   19.9152  -0.910  0.37361
RegionNiedersachsen            28.0733    13.3263   20.1936   2.107  0.04785 *
RegionNordrhein-Westfalen      14.6202    12.6617   20.0445   1.155  0.26180
RegionSachsen                 -48.3686    21.3624   19.9147  -2.264  0.03488 *
RegionSachsen-Anhalt           53.5481    22.5998   19.9612   2.369  0.02801 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

F1

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F1 ~ Vowel + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 2405.7

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.3398 -0.4955  0.0316  0.4471  5.0528

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept)  6996     83.64
 Residual             38839    197.08
Number of obs: 180, groups:  ID, 30

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
(Intercept)   950.25      28.31   51.13  33.567   <2e-16 ***
Vowel2       -363.93      29.38  149.00 -12.388   <2e-16 ***
Sexm         -131.00      50.10   28.00  -2.615   0.0142 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

F2

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: F2 ~ Vowel + Sex + (1 | ID)
   Data: dataset

REML criterion at convergence: 2334.7

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.9794 -0.4330  0.0082  0.4977  5.5164

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 13880    117.8
 Residual             22918    151.4
Number of obs: 180, groups:  ID, 30

Fixed effects:
            Estimate Std. Error      df t value Pr(>|t|)
(Intercept)  1791.83      29.95   37.84  59.832  < 2e-16 ***
Vowel2       -106.68      22.57  149.00  -4.727 5.23e-06 ***
Sexm         -221.30      57.43   28.00  -3.854 0.000621 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Spectral tilt

```
> summary(best_model)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: spectral_tilt_Praat ~ Vowel + (1 | ID)
   Data: dataset
```

```
REML criterion at convergence: -1835.8

Scaled residuals:
     Min       1Q   Median       3Q      Max
-2.91200 -0.53389 -0.03532  0.49464  3.06067

Random effects:
 Groups   Name        Variance  Std.Dev.
 ID       (Intercept) 1.502e-06 0.001226
 Residual             1.233e-06 0.001110
Number of obs: 179, groups:  ID, 30

Fixed effects:
              Estimate Std. Error         df t value Pr(>|t|)
(Intercept) -6.228e-03  2.525e-04  3.620e+01  -24.66   <2e-16 ***
Vowel2       2.437e-03  1.660e-04  1.480e+02   14.68   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```