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The Impact of Emotional Distractors In Visual Search: Mechanisms Of Attentional Capture And Learning-Based Suppression

S.S.D. BIOS-06/A

Coordinator: Prof. Alberto GAJOFATTO

Signature ____________________

Supervisor: Prof. Leonardo CHELAZZI

Signature ____________________

Doctoral Student: Dott.ssa Sena BIBERCI

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ABSTRACT

In an environment saturated with information, maintaining focus on goal-relevant input can be challenging. Even when our objectives clearly define what to attend to, irrelevant stimuli often intrude. The question of why this happens has multiple answers, but they can largely be covered by one concept: "salience." Although individuals may successfully complete a task, the presence of salient but irrelevant information can lead to longer response times and increased error rates, which may, in turn, have significant negative consequences. While the impact of physically salient distractors has been shown repeatedly, the influence of emotionally salient distractors, especially those with negative valence, remains relatively understudied. Therefore, we investigated whether emotionally salient, task-irrelevant stimuli disrupt attention in a manner similar to physically salient ones and hypothesized that their distracting power would be more resistant to suppression despite learning-dependent control mechanisms. By integrating behavioral and eye-tracking measures, our study highlights the dynamic interplay between emotion, salience, and learning in guiding attentional selection, providing new insights into how attentional control deals with complex, emotionally salient stimuli.

As a first step, we conducted a standardization study in which participants rated peripherally presented pictures in terms of valence, arousal, complexity and recognizability. This ensured that peripheral presentation did not significantly alter perceptual evaluations of emotional pictures and allowed us to match neutral and negative pictures for complexity, while distinguishing them for valence and arousal. In the second experiment, we assessed the impact of salient distractors during a classic visual search task. Participants were asked to identify the target defined with a distinct outline shape and indicate whether a white dot appeared above or below it. Search displays included either simple geometric shapes (i.e., squares) or pictures, with a salient distractor present in 60% of trials. Finally, the third experiment examined whether increasing the spatial predictability of distractor appearance across locations would reduce their impact. Our results confirmed that the presence of both simple geometric and picture distractors reduced accuracy and increased reaction times relative to distractor-absent trials, replicating classic attentional capture effects observed in visual search paradigms.

This finding confirms that salient stimuli, regardless of their nature, compete for attentional resources and disrupt goal-directed behavior. Furthermore, emotionally negative distractors exerted even a stronger and more persistent effect, highlighting the difficulty of ignoring emotionally charged stimuli, even with repeated exposure or predictable spatial presentation.

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Chapter 1: INTRODUCTION

INTRODUCTION

"My experience is what I agree to attend to. Only those items which I notice shape my mind."

William James (1890)

I could not agree more with William James (1890), who argued that the things that captivate our attention ultimately shape our experience of the world. Nevertheless, I would also argue that what we fail to attend to remains outside our reality. Given that our surroundings contain far more information than we can ever process at once, if this were strictly true, we would only experience a tiny fraction of the world around us. Indeed, we now understand that we do not simply "attend" or "not attend" to information; information can also be "suppressed" (Chelazzi, Marini, Pascucci, & Turatto, 2019; Geng et al., 2019). Although both "suppression" and "not attending" result in the filtering out of some information, suppression, unlike *not attending*, involves an additional stage of processing that allows the encoding of information before it is filtered out. Starting from what motivated the researchers and myself, we will delve into how information is selected and what happens to information that does not make it into selection.

Depending on the diversity and demand of the situation, the brain adapts itself, directs attention toward what is relevant, and shapes behavior accordingly (Reynolds & Chelazzi, 2004; Theeuwes & Failing, 2020; Geng, 2014; Acunzo, Grignolio, & Hickey, 2024). This process of selecting information and acting has often been explained through metaphors. One of the most prominent in the literature is the *"spotlight metaphor"* (Posner, Snyder, & Davidson, 1980). According to this metaphor, since it is not possible to direct our attention to an entire visual space simultaneously, attention works much like a spotlight on a theater stage: just as the light can only illuminate one area at a time, our attention can also be directed toward a specific location at a time. By shifting attention from one place to another, we ensure that the whole visual space can eventually be processed. At this point, one may only wonder why you attend to what you attend.

The answer is not straightforward and depends on multiple factors. Given the limited capacity of attention, the information present in our environment must compete for processing (Desimone & Duncan, 1995; Zehetleitner, Koch, Goschy, & Müller, 2013), and only the selected information is carried forward for further processing (Kastner & Underleider, 2001), while unselected items fade out.

Since the 1990s, the relationship between how we select relevant information (target selection) and ignore irrelevant information (distractor suppression) has attracted considerable interest, leading to the development of multiple theories and empirical investigations that attempt to clarify this interaction. Attentional control is now known to be governed by a complex interplay of several mechanisms that bias information processing towards the most relevant (Sawaki & Luck, 2010). These mechanisms can be broadly grouped into three categories: bottom-up (stimulus-driven) control (*see Chapter 2.1: Bottom-Up Attentional Control*), top-down (goal-driven) control, (*see Chapter 2.2: Top-Down Attentional Control*), and a more recently emphasized mechanism based on selection history (*see Chapter 2.3: Selection History)*. The terms we are addressing here have been referred to by different names throughout history. This is because the way these phenomena were observed changed across time, shifting from philosophical interpretations to behavioral approaches, and later to neural (Hickey, McDonald, & Theeuwes, 2006; Hickey, Di Lollo, & McDonald, 2009; Van Zoest et al., 2021; Ferrante et al., 2023) and cognitive perspectives. For instance, Descartes was the first to attempt to distinguish between the voluntary and automatic shifts of attention. He called the term "attention" to refer to the voluntary control of the orientation of attention to an object, and he used the term "admiration" referring to the objects that capture our attention involuntarily. Starting with Descartes, the distinction between voluntary and involuntary attention was given many other terms; for instance, voluntary control of attention was referred to as "intellectual" and involuntary control of attention was referred to as "sensory" by James (1890). The sensory control was later explained as involuntary because it captures attention effortlessly by an unattended stimulus. Instead, the intellectual control involved anticipatory preparation, sending "attend-to" signals to related cognitive centers. Nowadays, we refer to them as "stimulus-driven" and "goal-driven" attentional processes. Although the terms continue to evolve, not only does the debate persist, but it is also challenged by a new phenomenon that influences attentional processes independently of either factor. This new attentional control mechanism, known as "selection history", explains how our current behaviors are influenced by prior experiences. It represents a broad category of learning experiences that shape the attentional system, and encompasses several distinct processes, referred to as statistical learning, reward-driven attentional capture, and intertrial priming (Theeuwes et al., 2022; Anderson et al., 2021; Duncan & Theeuwes, 2020; Theeuwes, 2018; Chelazzi et al., 2013; Awh et al., 2012; Della Libera, Perlato, & Chelazzi, 2011).

As mentioned above, the competition among multiple stimuli is modulated by multiple factors, such as by current goals (Ferrante et al., 2018; Corbetta & Shulman, 2002), motivational relevance (*reward:* Della Libera & Chelazzi, 2006, 2009; Hickey, Chelazzi & Theeuwes, 2010; Chelazzi et al., 2013; Padmala, Sambuco, & Pessoa, 2019; *emotion:* Ferrari et al., 2008; Walsh et al., 2018; Pourtois, Schettino, & Vuilleumier, 2013; Pessoa, 2013; Straub, Kiesel, & Dignath, 2020; *addiction:* Field & Cox, 2008; Della Libera et al., 2019), and also by the physical salience of the stimuli (Theeuwes, 2010; Chang & Egeth, 2021; Zehetleitner et al., 2013; Vicente-Conesa et al.,

2023) as well as by one’s past experiences (Awh, Belopolsky, & Theeuwes, 2012; Failing & Theeuwes, 2018; Jiang, Sha, & Sisk, 2018; Vatterott, Mozer, & Vecera, 2018; Chen et al., 2025).

A simple observation exercise can illustrate how selective attention operates in everyday contexts. The next time you go out with a friend, ask each other at the end of the evening to express five aspects of the environment that you noticed. You will likely find that your answers show little overlap, except when a highly salient event occurred, such as an unexpected loud noise, a sudden flash of light, or an unusually distinct outfit. While these striking elements tend to be recalled consistently, the more subtle features of the environment are remembered quite differently. This discrepancy prompts a fundamental question: why do certain events capture attention so much more strongly than others?

This everyday observation has inspired numerous researchers to systematically examine the problem in the laboratory, particularly through certain behavioral paradigms (Theeuwes, 1992; De Tommaso & Turatto, 2019; Wang & Theeuwes, 2020; Kong, et al., 2020; Huang & Li, 2023), which are highly informative for demonstrating the interplay between efficient task-relevant information (i.e., target) selection and task-irrelevant information (i.e., distractor) suppression strategies. A closer look at the literature reveals a wide range of experimental paradigms for investigating the control mechanisms of visual selective attention. One widely adopted paradigm is the Posner cueing task (Posner, 1980), and it has been used extensively to study voluntary attentional control. In this paradigm, participants are cued to attend to a location on the display screen prior to the target onset. This experimental design allows the understanding of how anticipatory cues can facilitate target detection and reduce distractor interference. Another one is the go/no-go task (Donders, original work: 1868, English translation: 1969), where some trials require a behavioral response, while others require its inhibition. For instance, participants might be asked to press a key when a green circle appears (go trials) but withhold their response when a red circle is presented (no-go trials). Through this experimental design, researchers aimed to illustrate inhibitory control mechanisms and how response inhibition interacts with distractor suppression by comparing the timing of their behavioral responses across two conditions. On the other hand, the Eriksen flanker task (Eriksen & Eriksen, 1974) provides another practical approach to observe the efficiency of selective attention in filtering out task-irrelevant information. In this task, participants are asked to respond to a centrally presented target, while ignoring peripherally presented distractor stimuli. A typical example is to identify the direction of a central arrow while ignoring neighboring arrows that may point in the same (i.e., congruent trial) or opposite (i.e., incongruent trial) direction. This task has been particularly influential in understanding conflict monitoring and interference control. Last but not least, another example is the classical visual search paradigm (Theeuwes, 1992), in which participants are asked to search for a unique target item (e.g., by shape or color) among other items presented in either homogenous (sharing feature with the target) or heterogeneous (differing features from the target) displays, and to report the orientation of the line within the target item. In some trials, a salient but task-irrelevant item (i.e., a distractor differing in another feature dimension) is also presented. Taken together, these diverse behavioral paradigms have provided valuable insights into how attention selects relevant information while ignoring irrelevant input. One common and undeniable finding is that salient but task-irrelevant stimuli impair performance (Geng, 2014; Liesefeld, Tollner, & Müller, 2017; Chang, & Egeth, 2021). However, it has also been shown that their distracting power can be controlled through the engagement of attentional control mechanisms. These mechanisms come into play and help reduce interference from distracting stimuli only when task conditions permit their implementation. For instance, when certain stimuli are repeatedly presented in a specific context with consistent regularities, we can unconsciously detect these regularities, which then enables us to guide our attention more efficiently (Wang & Theeuwes, 2018; Huang, Theeuwes, & Donk, 2021; Huang et al., 2021). They may bias us toward looking at a location that is more likely to contain task-relevant information, or they may prompt us to shift our attention away from it when it is irrelevant to our current task. As a result, distractor interference is reduced when distractors appear at a high-probability distractor location (Wang & Theeuwes, 2018), indicating an additive control driven by learned regularities (Ferrante et al., 2018; Chen et al., 2025).

Yet, the beauty of science is that every answer leads to new questions. The reduced, or even absent, interference by task-irrelevant stimuli when they are "ignored" raised a critical question: when attention is shifted away from a stimulus, is it completely excluded from further processing, or is it suppressed through distinct attentional control mechanisms? We further try to answer these questions in *Chapter 2*.

1. AIM OF THE STUDY

Reflecting on my own experimental work over the past three years, one of the most immutable insights has been the complexity of our visual world, which cannot be easily reproduced in the laboratory. Traditional studies of attention often rely on simple stimuli, such as pure tones, words, contrast manipulations, or geometric shapes, to isolate specific attentional mechanisms. While highly informative, this approach overlooks a fundamental aspect of what might be called "natural selective attention" (Lang, Bradley, & Cuthbert, 1997). In real-world contexts, attentional selection is strongly shaped not only by low-level perceptual features (such as color or luminance contrast), but also by semantic and emotional content. Especially in situations where survival is at stake, attention is primarily guided by motivational significance. Stimuli that carry motivational value are more likely to capture and sustain attention than routine, affectively neutral events (Foxe & Snyder, 2011; Vuilleumier et al., 2001; Murphy et al., 2020; Hindi-Attar, Andersen & Müller, 2010; Hodsoll, Viding & Lavie, 2011; de Haro et al., 2020).

Guided by these considerations, my intention has always been to bring experimental designs closer to the richness of real-world experience. Throughout my doctoral research, I was driven by a simple yet persistent question: Do attentional biases arise primarily from accumulated experiences, from the intrinsic properties of external stimuli, or from the dynamic interaction of both? My work represents an initial step toward understanding this question and suggests that these processes may not be mutually exclusive, but instead overlap, build on one another, and operate together in complex ways. Pursuing this line of thought, a central goal of my research has been to disentangle the relative contribution of emotional salience in shaping attentional priority, and to examine how this interacts with the competition introduced by highly salient perceptual features.

In this thesis, we adopted a broader and more inclusive approach to defining "emotional" stimuli, while remaining fully aware that personal experiences can assign additional significance to so-called neutral stimuli, rendering them emotionally positive or negative for each individual. Indeed, insights from research on phobias and addictions illustrate how both intrinsic (innate/shared) and acquired (experience-based) emotional values can strongly influence attentional selection. However, before examining individual experiences with emotionally charged information, it is crucial first to understand how emotionally charged, specifically negative or unpleasant, complex stimuli interact with attentional control mechanisms.

Surprisingly, relatively few studies have directly examined whether emotional salience operates in the same way as physical salience. Negative stimuli in particular have historically been considered to capture attention in a bottom-up manner (Öhman, 1997), given that such capture is typically reflexive, involuntary, and can occur in the absence of conscious awareness (Carretié, 2009). What remains unclear, however, is whether repeated exposure can diminish their attentional priority through habituation and learning, or whether their affective salience confers a degree of resistance to suppression that physically salient stimuli do not possess.

Moreover, it is not fully understood which and how attentional control mechanisms adapt when such stimuli are encountered. Addressing these issues is crucial for understanding the dynamics of attentional selection and for determining whether negative information constitutes a distinct case within attentional selection. Therefore, in this project, I have sought to examine *"if"* and *"how"* emotional task-irrelevant stimuli can be suppressed, and I am currently exploring *"when"* this modulation occurs.

1.1. Research Questions

Building on the theoretical and empirical considerations discussed above, the present thesis aims to investigate the interaction between attention and emotion, with a particular focus on negative emotional stimuli. Specifically, it examines how emotional, task-irrelevant stimuli influence attentional allocation and whether their disruptive effects can be modulated through learning and experience, namely statistical learning. In other words, in spite of effective learned suppression, induced through statistical learning, negative stimuli might bypass the suppression and might not benefit from it.

In Experiment 1, the goal was to standardize the emotional pictures selected from various sources and to assess whether their evaluation changes when presented peripherally rather than foveally. According to Lang, Bradley, and Cuthbert (1997), the picture stimuli successfully elicit a wide range of emotional reactions, varying in both intensity and valence, encompassing pleasant and unpleasant affective states. They propose that the motivational states triggered by these affective cues are fundamentally similar to those engaged when organisms pause, attend, and scan their environment for signals of potential danger, social significance, or opportunities for reward. Therefore, the main question addressed in Experiment 1 was whether peripheral presentation alters the evaluation of emotional pictures, given that stimuli appearing outside the focus of attention may be processed differently.

In Experiment 2, our focus shifted to studying how task performance is influenced by the presence of emotionally salient distractors within a classic visual search paradigm. In particular, the experiment aimed to investigate how attentional mechanisms operate when attention is challenged by negative, distracting stimuli, in order to determine whether emotionally salient distractors are more difficult to suppress than physically salient ones, thereby providing insight into the power of emotional interference in attentional control. For this purpose, the task was modified to allow the use of complex, emotionally salient, task-irrelevant stimuli in addition to more simple, geometrical stimuli. Importantly, this design enabled us to directly observe competition between task-relevant and -irrelevant information, both simple and complex. For this reason, the present study differs from much of the previous work using emotional distractors. Much of the evidence with emotional distracting stimuli comes from experimental paradigms in which only a single stimulus is presented, and therefore no competition for attentional resources is present. In many earlier studies, emotional stimuli were introduced as additional elements presented outside the task itself. For example, Ferrari and colleagues (2011), and Murphy and colleagues (2020), asked participants to search for a target letter while a pleasant or unpleasant picture was displayed at the center of the screen. Similarly, De Cesarei et al. (2025) required participants to detect a digit target while an emotional image was presented directly in the fovea. In both cases, the target and distractor did not share visual features, and therefore, we could assume that they did not directly compete for processing. In contrast, Theeuwes and van Moorselaar (2024) employed a classic visual search task to investigate the impact of emotional stimuli when both the target and distractor were presented within the same context. However, in their task, targets were simple geometric shapes (diamonds and circles in a singleton search), while emotional distractors consisted of icons such as butterflies, spiders, or leaves. As in earlier studies, the target and distractor differed substantially in their visual properties. Across many of these studies, a crucial element has been missing: the target and distractor rarely shared the same feature space, meaning they were unlikely to compete for processing at the same level of construction. Additionally, the use of simple geometric shapes, again, provides a limited approximation of the complexity of real-world visual environments (Wöstmann et al., 2022). The present experiment, instead, used visually complex emotional stimuli that more closely reflect real-world processing demands, ensuring that the target and distractor compete directly for attentional resources. Taken together, our paradigm provides a more ecologically valid and theoretically informative test of emotional distraction, capturing competition at a level that previous experimental designs were unable to achieve.

Finally, in Experiment 3, we explored whether learning-based control mechanisms (i.e., statistical learning) can adapt to reduce interference from emotionally salient distractors, or whether such mechanisms have limited power when the distracting stimulus carries emotional significance. By extension, the findings may further inform whether suppression within the statistical learning paradigm is valence-specific or instead driven solely by frequency. To this end, the experiment investigated the extent to which emotional distraction can be modulated through a statistical learning.

Chapter 2: THE DETERMINANTS OF ATTENTIONAL SELECTION

THE DETERMINANTS OF ATTENTIONAL SELECTION

When interacting with the world, the visual system is continuously confronted with an overwhelming amount of information. Because it is not possible to process everything at once, attentional selection serves as a fundamental mechanism that allows certain information to be prioritized for further processing, while other bits of information are filtered out. For a long time, attentional selection has been described as a dichotomous process driven either by bottom-up factors, such as the physical salience of a stimulus, or by top-down factors, such as an observer's current goals and intentions (Corbetta & Shulman, 2002; Wolfe, 1994, 2021). However, this dichotomy appears to be incomplete. Recent work proposed that in addition to stimulus-driven and goal-driven influences, attentional selection is also shaped by past experiences. Previous episodes of selection, what is often referred to as selection history, can bias attention toward or away from certain stimuli or locations, even in the absence of explicit goals or physical salience (Wolfe, 2021; Kong et al., 2020). This implies that attentional selection mechanisms are multifaceted and these three sources of attentional control, bottom-up salience, top-down goals, and selection history, together shape the attentional priority map. Accordingly, this map represents the priority of stimuli at that given moment across the visual scene (Failing, Wang, & Theeuwes, 2019).

In the following subsections, we provide an overview of the key mechanisms underlying visual selective attention and explain their relevance to the present study. We begin by considering bottom-up attentional selection, which is driven by the physical salience of stimuli and plays a critical role in determining how and why certain elements capture attention. We then discuss top-down attentional selection, which reflects the influence of task demands and current goals, emphasizing the observer's voluntary control over attentional allocation. Finally, we focus on selection history, which constitutes the central theme of the present project, with particular emphasis on statistical learning as a mechanism through which past experience shapes attentional priority over time.

1. BOTTOM-UP ATTENTIONAL CONTROL

Bottom-up attentional control, also known as “stimulus-driven” or “exogenous control,” is guided by the stimulus’s physical features (e.g., color, shape, motion) (Gaspelin, Leonard, & Luck, 2017). This mechanism orchestrates the prioritization of highly salient stimuli for processing, regardless of their relevance to the task. Consequently, attention is initially captured by any item that stands out uniquely in the search display among other less salient items, independent of the observer's goals (Zehetleitner et al., 2013; Chang & Egeth, 2021). Nonetheless, the effectiveness of a salient stimulus in capturing attention depends highly on its distinctiveness relative to other items in the display. When attention is drawn to the most salient but task-irrelevant item in the visual field, this diversion can lead to delays, reduced efficiency, or even a complete disengagement from the initial goal (Geng, 2014; Duncan & Theeuwes, 2024). The time required to engage and disengage from a distractor and redirect attention to the target has a critical role in determining the efficiency of goal-directed behavior.

Before proceeding, it is important to clarify what is meant by “salience”. Stimulus salience refers to the degree to which a stimulus stands out from its surrounding context and captures attention due to its perceptual distinctiveness (Liesefeld et al., 2024). Importantly, salience is not an absolute property of a stimulus, rather, it is relative and context-dependent, determined by the degree of feature contrast with surrounding stimuli (Itti & Koch, 2001; Kastner & Ungerleider, 2001). Taken together, salience is a continuous, graded construct rather than an all-or-none property, emerging from complex interactions among features within the visual scene (Fecteau, & Munoz, 2006; Wolfe, & Horowitz, 2017). Beyond purely visual characteristics, salience can also arise from motivational and affective properties (Pessoa, 2005; Pourtois, Schettino, & Vuilleumier, 2013; Brosch et al., 2008). Converging evidence indicates that stimuli carrying negative emotional valence or high intrinsic value, such as those associated with reward, can engage bottom-up attentional mechanisms, and attain elevated priority in selection, even in the absence of task relevance (Öhman, Flykt, & Esteves, 2001; Carretié, 2014; Anderson et al., 2022).

The capture by salient items is assumed to be highly dependent on the interaction between target and distractor features, as well as their predictability, and task requirements (Theeuwes, 1991; Gaspelin et al., 2023; De Waard & Theeuwes, 2026). The attentional capture effect by uniquely colored distractors was repeatedly demonstrated in the additional singleton paradigm, in which participants looked for a stimulus with a unique shape (e.g., a circle among squares) while a colored distractor appeared in some trials (Wang & Theeuwes, 2020). However, when a unique shape search was done in the presence of various shape stimuli, in a heterogeneous display, the capture effect disappeared (Bacon & Egeth, 1994; Leber & Egeth, 2006a). This effect was explained by the activation of one of the two search modes, depending on the task requirements: the singleton-detection mode and the feature-search mode (Huang, Donk & Theeuwes, 2022). In the singleton-detection mode, participants search for an item that differs from the other stimuli in the display. The search is conducted in a parallel manner across all items in the display (Treisman & Gelade, 1980), which allows distractors to capture attention when they are more salient than the target (Theeuwes, 2023). In this case, attention is assumed to be completely stimulus-driven and therefore, makes participants susceptible to attentional capture by irrelevant but salient stimuli (Liesefeld et al., 2024). In contrast, in the feature-search mode, participants look for a specific feature, such as a particular color, allowing them to effectively ignore irrelevant singletons (Gaspelin et al., 2023). The effective control is achieved through activating the top-down mechanisms for searching the target stimulus in a serial manner and it results in less, or even an absence of, attentional capture by irrelevant stimuli (Chelazzi et al., 2019; Theeuwes, 2023; De Waard & Theeuwes, 2026). Especially, when salient distractors differ from the target-defining feature, they can be easily ignored, resulting in no attentional capture. Although this generally holds true, this kind of search was recently found to be effective only when a non-salient target is presented within a display containing few elements (Theeuwes, 2023). Because the target is non-salient and therefore difficult to detect, successful selection can be achieved only through a serial search (Duncan & Humphreys, 1989; Wang & Theeuwes, 2020; Theeuwes, 2023).

Gaspelin and colleagues (2015) provided further evidence for attentional capture by salient items. In their study, participants performed a visual search task in which they had to identify a target with a different shape among other stimuli, and some of the trials included a highly salient color singleton. In a subsequent probe task, participants' memory for distractor location was tested. They found that the suppression effect observed in the probe task was significantly correlated with the capture effect in the visual search task. In other words, when a highly salient singleton distractor was presented, attentional resources were initially directed to its location, resulting in higher recall accuracy at the singleton distractor location compared to nonsingleton distractor locations. For larger search arrays, singleton distractors captured attention even when participants were encouraged to engage feature-search mode to locate the target. High probe recall accuracy at the salient singleton distractor location suggests that attention is allocated to the salient singleton distractor, leaving fewer resources to process the target.

Figure 1: Illustrative Example of Salient Stimuli

To summarize, on the one hand, salient items capture attention in an automatic, stimulus-driven manner, and it has often been assumed that such distraction is unavoidable. On the other hand, there are situations in which top-down control allows observers to prioritize task-relevant targets over irrelevant stimuli. Traditionally, these perspectives suggested an “either capture or control” view. To resolve this debate, the “signal-suppression account” was proposed (Sawaki & Luck, 2010; Gaspelin & Luck, 2018b; Luck et al., 2021; Gaspelin, Ma, & Luck, 2025). According to this view, although salient items initially capture attention, the interference caused by salient but task-irrelevant information (i.e., distractors) can be prevented by engaging top-down, feature-based control mechanisms, even though these distractors continue to generate strong bottom-up signals (Feldmann-Wüstefeld, Weinberger, & Awh, 2021; Feldmann-Wüstefeld, & Vogel, 2019; Gaspelin et al., 2015, 2017; Chelazzi et al., 2019; Chang & Egeth, 2021; van Moorselaar & Slagter, 2019ab; Theeuwes, 2023). These findings suggest that attentional capture is not purely automatic, but can be modulated by the observer’s current goals, highlighting an important top-down influence on selective attention (Stilwell & Gaspelin, 2021).

2. TOP-DOWN ATTENTIONAL CONTROL

Top-down attentional processes are referred to as “goal-driven”, “endogenous control”, and “volitional”, and this form of control allows us to intentionally focus on specific aspects of a visual scene (Corbetta & Shurman, 2002; Theeuwes & Van Moorselaar, 2024). Even though the voluntary act of orienting has often been considered fundamental, some researchers have preferred to adopt a broader definition of top-down attentional processes, referring to them as any mechanism that is not purely perceptual and may also be influenced by factors such as “context”, “learning”, or the “observer’s expectations” (Gaspelin & Luck, 2018ab; Theeuwes & Failing, 2020).

The idea that attentional capture is shaped by the observer’s current goals proposes that people create an internal “attentional set” or “feature-based priority map” centered on the target-defining attributes (Wright & Ward, 2008). For example, in a classic visual search task, participants are asked to respond to a target defined by a specific feature within a heterogeneous display. Because the target feature is predefined, such as a specific shape among other shapes, and is not simply the most unique item, participants are expected to serially inspect each element of the visual scene while keeping the target-defining feature in mind (feature-search mode). A great practical example that illustrates this would be when someone points out how many red cars are on the street. We may begin to search for them and eventually realize, often with surprise, how frequent they actually are. Under these conditions, participants are thought to rely on top-down control (Huang, Donk, & Theeuwes, 2022), detecting the target more accurately and rapidly, and consequently being more successful in mitigating the disruptive effects of task-irrelevant but salient items.

However, this effect may even generalize, such that while initially searching for red cars, we become more broadly sensitive to all red objects (Treisman & Gelade, 1980; Wolfe, 1994; Leber & Egeth, 2006a; Gaspelin & Luck, 2018b). Even if the observer's main goal is to look for a red car, they may become more susceptible to attentional capture by other red objects. Paradoxically, in this case, adopting a feature map can itself become a source of disruption once the prioritized feature is no longer relevant. It may cause observers to momentarily interrupt the ongoing selection process, and involuntary be capture by irrelevant items (Folk et al., 1992).

Importantly, these attentional sets are assumed to be highly specific to target-defining features. For instance, in the Posner cueing paradigm, Folk, Remington, and Johnston (1992) demonstrated that only cues sharing the target's defining feature captured attention. The cue was either a color singleton or a sudden onset stimulus. The findings showed that only onset cues captured attention when participants searched for an onset target, and when they searched for a color-defined target, only color cues were effective in capturing attention. Cues lacking the target-defining feature failed to capture attention despite being physically salient, indicating that attentional capture depends on the observer's goal-driven attentional settings rather than solely driven by stimulus salience (Theeuwes, 1991; Yantis & Jonides, 1990; Yantis, 2000).

Instead, when the target and distractor share similar features, such as red and orange rather than red and green, capture can be attenuated. This occurs because similar features suppress one another, enhancing the perceptual prominence of feature differences (Liesefeld et al., 2024). In other words, the attentional template becomes further tuned to emphasizes the dissimilarity between target-relevant and irrelevant features, thereby reducing distractor interference (Chelazzi et al., 2019; Huang, Donk & Theeuwes, 2022), and the greater the overlap between the target and distractor feature maps, the more effectively the distractor can be suppressed.

However, recent findings showed that attentional control is not exclusively top-down either. Hickey, McDonald, and Theeuwes (2006) also challenged the idea of purely top-down attentional control. They conducted a series of visual search experiments to show the capturing effect of salient but task-irrelevant stimuli (i.e., distractors). Their findings supported the idea that salient distractors unintentionally capture attention, providing evidence in support of the "stimulus-driven" account (*see Section 1*). Wang and Theeuwes (2018) provided further support for the idea that attention initially shifts toward the most salient item in the display, and then quickly disengages. According to the "Rapid Disengagement Account" (Theeuwes, 2010), suppression is not possible without an initial attentional shift to the salient item. Once this shift occurs, top-down control mechanisms may then come into play to redirect attention away from the distractor following its initial capture. In their study, cued distractor location did not produce an inhibition effect of distractors, instead, when the target was presented in that location, participants detected the target faster than when it appeared in a non-cued location. They interpreted these results as evidence that the cued location was first attended to and then inhibited.

3. SELECTION HISTORY

More recently, research has highlighted that attentional selection is not solely determined by the interplay between top-down and bottom-up factors but is also strongly influenced by selection history (Failing & Theeuwes, 2019; Theeuwes, 2019). The influence of selection history relies on two core ideas: first, that attentional allocation is shaped by prior experience with stimuli, and second, that these effects cannot be reduced to changes in current goals or intentional strategies. Selection history gives rise to persistent experience-dependent attentional biases that reflect both long-term learning processes, such as reward and punishment-based learning (Della Libera & Chelazzi, 2009; Schmidt, Belopolsky, & Theeuwes, 2015), and short-term influences, such as recent trial history (i.e., intertrial priming) and repeated exposure to contextual regularities (Awh, Belopolsky, & Theeuwes, 2012; Failing & Theeuwes, 2019).

One prominent impact of selection history is that locations or stimulus features that have been attended more frequently in the past are more likely to be selected again (Ferrante et al., 2018; Theeuwes, 2019). Specifically, stimuli appearing at previously attended locations, or sharing previously relevant features, are processed more efficiently when they serve as targets and are more disruptive when they serve as distractors. This suggests that selection history leaves residual traces that bias future attentional selection, and these biases are thought to arise because repeated selection strengthens the selection signal associated with specific locations or features. The impact of selection history on attentional selection has been most clearly demonstrated in studies of intertrial priming (Meeter & Olivers, 2006), which represents its most basic form. However, similar effects have also been observed in contexts involving reward learning or threat associations (Anderson, Liao, & Grégoire, 2022; Kim & Anderson, 2021). Importantly, these selection history-driven biases can persist even when the previously selected stimulus becomes entirely task-irrelevant and lacks physical salience (Failing, Wang, & Theeuwes, 2019).

Therefore, this effect cannot be explained by top-down control in which experience influences attention directly by modifying the observer's goals, which leads to a strategic, voluntary shift in attentional focus, unlike selection history in which prior experience exerts a direct and involuntary influence on attentional selection, independent of the observer's current intentions or conscious control (Anderson, 2013; Theeuwes, 2018). As such, selection-history biases operate automatically by changing the representational priority of stimuli and locations, integrating implicitly acquired knowledge into the attentional priority map, and persist even when the learned information is no longer relevant, indicating that attentional control is fundamentally shaped by prior experience (Duncan, van Moorselaar, & Theeuwes, 2023).

3.1. Reward and Punishment

Reward, punishment, and aversive learning (Schmidt, Belopolsky, & Theeuwes, 2015; Chen et al., 2025) each constitute a powerful mechanism through which selection history biases attentional allocation (Anderson, Liao, & Grégoire, 2022). Their effects on attention are complex and assumed to be context dependent (Failing & Theeuwes, 2018; Chelazzi et al., 2019; Anderson et al., 2021).

While stimuli associated with negative outcomes may attract attention due to their motivational relevance, which is consistent with theories emphasizing threat detection and survival (Öhman, 1997; Pessoa, 2013; Kim & Anderson, 2021, *see Chapter 3*), stimuli that have been previously associated with reward, may gain increased priority and can capture attention even when they are no longer relevant to the task at hand or aligned with current goals, which is sometimes referred to as value-driven attentional capture. Importantly, in both cases attentional priority is shaped by learned value rather than physical salience or top-down relevance (Anderson, Laurent, & Yantis, 2011; Anderson, 2013; Failing & Theeuwes, 2018), and learned value attentional biases can persist long after value related contingencies are removed, indicating that attentional control is not reset on a trial-by-trial basis but reflects longer-term learning history (Theeuwes & Failing, 2020). For instance, once a particular shape becomes associated with a reward, it can continue to capture attention even after it is no longer relevant to the task and no longer provides a reward (Della Libera & Chelazzi, 2009). This form of non-strategic attentional capture is commonly attributed to selection history. This outcome confirms that past experience has a direct influence and further indicates that these effects cannot be explained by changes in current goals or intentional strategies (Awh, Belopolsky, & Theeuwes, 2012; Luck et al., 2021).

3.2. Statistical Learning

The statistical learning mechanism is an implicit ability that allows us to extract regularities from our environments over time in order to generate predictions about future sensory input (Aslin & Saffran, 2025). Statistical learning phenomena were initially observed in the domain of language acquisition (Saffran, Aslin, & Newport, 1996; Romberg & Saffran, 2010). Subsequently, researchers began to investigate it more extensively after recognizing that it is a domain-general learning mechanism that has two main forms, namely, location-based, and object-based (Chen et al., 2025; Huang & Li, 2023), and is observable across a wide range of contexts, such as music and dance (i.e., motor learning), and other repetitive situations or behaviors (Kong et al., 2020). Events that occur repeatedly at specific times, intervals, or locations prepare individuals in advance for forthcoming occurrences. That is to say, statistical learning can manifest across both temporal and spatial dimensions, allowing individuals to form predictions about "when" and "where" events are likely to occur (Xu, Theeuwes, & Los, 2023). While temporal regularities allow the alignment of attentional resources with anticipated moments in time (Duyar, Ren, & Carrasco, 2024; Theeuwes & Failing, 2020), spatial regularities bias attention toward or away from specific locations (Ferrante et al., 2023; Wang & Theeuwes, 2018). These anticipatory modulations are in line with proactive attentional control, whereby learning influence sensory processing prior to display onset (Murphy et al., 2020).

The statistical learning mechanism making the environment more controllable by creating lasting attentional biases regarding both target and distractor locations (Ferrante et al., 2023). It may manifest as attentional spatial enhancement of the frequent target location or learned attentional spatial suppression of the frequent distractor location (Kong et al., 2020; Awh, Belopolsky, & Theeuwes, 2012). When statistical regularities are linked to target locations, performance is facilitated, leading to faster goal-directed responses (Ferrante et al., 2018; Geng & Behrmann, 2005). Conversely, when these regularities are associated with distractor locations, statistical learning functions as an efficient suppression mechanism, reducing the impact of distracting information (Britton & Anderson, 2020; Wöstmann et al., 2022). In other words, this mechanism of spatial enhancement and inhibition leads to the prioritization of information processing in specific regions of the visual field while deprioritizing others (Wang & Theeuwes, 2018). This idea aligns well with the "Spatial Priority Map" framework, which proposes that attentional weights across the visual field are dynamically adjusted based on experience and statistical regularities (Ferrante et al., 2018; Thayer & Sprague, 2023; Gaspelin et al., 2025). According to this framework, repeated events shape the spatial priority map, causing specific locations to gain higher attentional priority over time, as a result, attention is biased toward these locations even before the search display appears (Huang, Donk & Theeuwes, 2022). In short, thanks to the high adaptability of the attentional priority map, the system enables optimal adjustment to changing environmental conditions, facilitating the efficient selection of task-relevant information (Bisley & Goldberg, 2010; Awh et al., 2012), as well as building up a sustained distractor-filtering mechanism through exposure to frequent distractors.

The suppression effect has been demonstrated in multiple studies, where a salient distractor appears more frequently in one position, resulting in significantly reduced distractor cost and reduced probability of directing gaze at that position compared to other positions (Zhang et al., 2022; Failing & Theeuwes, 2020; Ferrante et al., 2018; Gaspelin & Luck, 2018b; Vicente-Conesa et al., 2023). This suggests that task-irrelevant information appearing in these prioritized regions is less likely to enter into strong competition for attention (Chelazzi et al., 2019). Importantly, this suppression occurs proactively, preceding the stimulus display and without conscious awareness of the spatial regularity (Wang & Theeuwes, 2018; Huang, Donk & Theeuwes, 2022).

The learning of statistical regularities not only facilitates the suppression of a location likely to contain a distractor but also the enhancement of a location likely to contain a target (Ferrante et al., 2018; Theeuwes & Failing, 2020). For instance, when a target repeatedly appears in the same location, that location becomes increasingly prioritized, leading to faster attentional selection (Zhang, Yang, Wang & Theeuwes, 2022). This enhancement reflects a bias in the spatial priority map favoring locations that are likely to contain the target. For instance, Huang and colleagues' (2022) results showed that a probe dot at the enhanced target location was detected faster than at other locations, indicating spatial enhancement prior to the actual search display.

These two processes, target selection and distractor suppression, may also indirectly impact each other, depending on whether stimuli are presented at high-probability target or distractor locations (Ferrante et al., 2023). For instance, when a target appears at a location typically associated with distractors, participants' responses to the target are slower because attention is suppressed at that location (Chelazzi et al., 2019; Britton & Anderson, 2020; Kong et al., 2020; Wang et al., 2019). Conversely, when a distractor appears at a high-probability target location, it tends to produce stronger interference (Zhang, Yang, Wang & Theeuwes, 2022). However, opposing effects have also been reported. Because more attentional resources are allocated to high-probability target locations, when a distractor appears there, disengagement from that location may occur more rapidly, suggesting that fewer resources for detecting targets lead to faster disengagement from distractors (Theeuwes, Kramer, & Atchley, 1999; Müller & Mühlenen, 2000; Geng & Behrmann, 2005; Goschy et al., 2014; Ferrante et al., 2018).

These findings suggest that suppression may not purely proactive, but also involves reactive processes (Ferrante, Jensen, & Hickey, 2025). Reactive control refers to the mechanism that is engaged after a distractor has captured attention, and in this case, it involves the disengagement from the distractor in order to execute the task (Grimshaw et al., 2018). If this is the case, the spatial regularities may not induce proactive suppression of the high-probability location, but instead simply prioritize it. When a location is prioritized, any event occurring there, whether it needs to be selected or suppressed, is processed more efficiently (Huang et al., 2025). In this sense, the distractor's position may have benefited from enhanced processing, such that both selection and reactive suppression mechanisms operate more effectively once attention was already biased toward that location. This interpretation aligns well with the rapid disengagement account (Theeuwes, 2010), which assumes that in such cases, attention may briefly engage with the distractor and then quickly shift away, facilitating its suppression. In other words, the distractor location may be proactively selected due to spatial regularities, and its suppression is ultimately strengthened through reactive suppression mechanisms. Nonetheless, Huang and colleagues (2022) reported contradictory evidence, showing that disengagement from a high-probability location was approximately equally fast regardless of the attentional weights allocated to that location.

Importantly, the attentional enhancement driven by statistical learning differs from top-down attention. This distinction was clearly demonstrated by Gao and Theeuwes (2020) in a visual search paradigm that combined visual search with a spatial working-memory cuing task. In this experiment, participants were instructed to orient their attention to a specific spatial location indicated with a letter cue before the search display onset, providing a measure of top-down attentional control. Meanwhile, the target was presented more frequently at one of the four locations, allowing statistical learning to influence performance implicitly. The results showed that when the cue (top-down) coincided with a high probability target location (statistical learning), participants' performance improved, as indicated by faster RTs. A similar effect was observed when distractor probability was manipulated at a specific location. The results indicate dissociable effects of these two mechanisms, showing that statistical learning operates independently of top-down attentional control. Moreover, Wang and Theeuwes (2018) replicated this finding using an additional singleton task. In their study, they cued a location that was likely to contain a distractor, expecting that if participants engaged top-down control mechanisms, the cue would facilitate effective distractor control. Although the cue produced no beneficial effect on distractor suppression, a small improvement in target selection was observed at the cued location in both Experiments 2 and 3. These results indicate some degree of cue processing; however, the use of top-down cuing alone was insufficient to control distractor interference. Instead, effective control was achieved by adjusting the weights in the spatial priority map through statistical learning. Participants were able to reduce the disruptive effect of salient distractors when they appeared at a high-probability location. These findings indicate that statistical learning and top-down attentional control operate independently (Duncan & Theeuwes, 2020; Kong et al., 2020).

In summary, a substantial body of evidence suggests that distractors repeatedly encountered are ignored more efficiently over time through experience-driven learning mechanisms, which have often been characterized as primarily spatial in nature and largely feature-blind (Huang, Donk & Theeuwes, 2022). In light of these findings, it is reasonable to expect that statistical learning may also modulate attentional responses to stimuli that are typically considered "hard-wired" to capture attention, such as fear-relevant stimuli. Accordingly, emotional distractors should exert a reduced impairing effect on target selection when their occurrence becomes predictable (Wöstmann et al., 2022; Xu et al., 2023). To date, however, relatively few studies have examined emotion as a defining feature of salience in distractors within a statistical learning framework. This gap is notable, given that although emotionally salient stimuli may benefit from adaptive processing advantages, their prioritization may nevertheless depend on processing demands and contextual regularities (Brosch et al., 2013).

3.3. Intertrial Priming

One of the clearest and simplest demonstrations that attentional selection is shaped by past experience is provided by intertrial priming. Intertrial priming reflects the effects of short-term selection history, arising from recent attentional events (Theeuwes & Failing, 2020). Target selection is facilitated when elements of the task are repeated from one trial to the next, including both target (Maljkovic & Nakayama, 1994; Kristjánsson & Campana, 2010; Meeter & Olivers, 2006) and distractor features (Goschy et al., 2014). For instance, distractors that appear at the same spatial location across consecutive trials tend to produce less interference than distractors presented at other locations (Duncan, van Moorselaar, & Theeuwes, 2023). This effect cannot be explained by either the top-down or the bottom-up attentional control perspective. Therefore, intertrial priming points to an experience-dependent mechanism that alters attentional priority based on recent selection history, operating independently of both goal-driven and stimulus-driven salience.

Moreover, in contrast with contextual cueing or statistical learning, intertrial priming is transient and fades rapidly, yet it can evoke a strong influence on attentional allocation. Importantly, such transient priming effects can be amplified or modulated by additional experience-dependent signals, such as reward, which further strengthens attentional biases toward recently selected stimuli (Della Libera & Chelazzi, 2006; Hickey, Chelazzi, & Theeuwes, 2010). However, besides the differences, intertrial priming and statistical learning can yield similar behavioral signatures; distinguishing between them is fundamental for interpreting attentional biases driven by selection history (Theeuwes & Van der Burg, 2011).

3.4. Contextual Cueing

Events and situations in the visual environment exist with structured regularities. As a result, visual attention is continuously shaped by patterns of information that co-occur together (Chun & Jiang, 1998). This phenomenon is known as contextual cueing and reflects a form of search facilitation where an observer's prior experience with a visual environment allows them to detect targets more efficiently (Leber & Egeth, 2006b; Goujon, Didierjean, & Thorpe, 2015).

Attentional selection is biased through learned contextual regularities such that targets are detected more efficiently when they appear in previously encountered contexts compared with novel ones (Kong et al., 2020). For instance, when participants search for a "T" target among "L" distractors, response times are faster when the same spatial configuration of the search display is repeated. This pattern indicates that observers implicitly acquire associations between spatial configurations and probable target locations (Chun & Jiang, 1998; Sisk, Remington, & Jiang, 2019).

Importantly, this phenomenon differs from statistical learning due to its involvement in relational processing between input and environment. Unlike the statistical learning, the regularity is not just about where the target or distractor is, but the persistent relationship between the target's location and the global configuration of surrounding non-target elements (Goujon, Didierjean, & Thorpe, 2015). Moreover, while the statistical learning effect is flexible but short-lived, contextual cueing is highly robust, with context memories persisting for weeks and resisting interference from new learning (Chun & Jiang, 1998; Britton & Anderson, 2020).

Together, these findings suggest that contextual cueing modulates attentional priority through expectations of the environment derived from past experience, thereby biasing processing toward locations predicted to contain relevant information.

Chapter 3: EMOTION

EMOTION

"Emotions are not reactions to the world; they are your constructions of the world."

Lisa Feldman Barrett (2017)

1. CATEGORIZING EMOTION

Defining what emotion is presents a long-lasting and fascinating challenge. Descartes (1649) was among the first to explore the question of emotions philosophically, and categorized emotions into six types: wonder, love, hate, desire, joy, and sadness. Since then, researchers have made significant progress in explaining the behavioral and neuropsychological basis of emotions (Gainotti, 2000; Leventhal & Scherer, 1982, 1987), leading to numerous theoretical models (Scherer, 2000; Ekman, 1984, 1999; Panksepp, 1989; Rolls, 2014). Although all of them require careful attention and offer valuable insights, only those most relevant to the present study are discussed here.

Across models, emotions are commonly observed and characterized through three main parameters: physiological responses (e.g., electrophysiological signatures, pupillary responses, changes in skin conductance), introspective or verbal reports (e.g., self-evaluative participative statements, questionnaires), and behavioral observations (e.g., overt behaviors, reward/punishment) (Eysenck, 1975; Bowers, Dietz, & Jones, 2014; Ward, 2015), with the important consideration that these distinct parameters are not necessarily correlated. All these parameters serve adaptive functions that enhance an organism's chances of survival.

From an evolutionary perspective, emotions are often conceptualized as motivationally tuned states of readiness, preparing the organism to respond effectively to biologically significant events

(Lang, Bradley, & Cuthbert, 1997). Accordingly, emotional states are assumed to be closely linked to action tendencies and to behaviors that are critical for approach or avoidance. Emotions are often most evident when ongoing behavior is interrupted, delayed, or inhibited (Lang, Bradley, & Cuthbert, 1997). This notion aligns well with Hebb's (1949) proposal that emotions arise when novel situations prevent the execution of expected behavioral responses, resulting in heightened neural and behavioral activation.

Building on these ideas, Konorski (1967) proposed a biphasic model of emotional responding, distinguishing between preservative and protective sensory-based reflexes. These reflexes were categorized according to their biological and motivational significances, with arousal modulating both types of responses. Further, Konorski claimed that these reflexive systems ultimately form the behavioral expressions of emotion. The biphasic model was further refined by Dickinson and Dearing (1979), who framed emotional behavior in terms of two opponent motivational systems: an appetitive system, activated by stimuli associated with reward and approach, and an aversive system, activated by stimuli associated with threat or punishment. Similarly, Rolls (2014) defined emotions as useful reinforcers that are elicited by rewards or punishers. A punisher is assumed to be a situation or an object that we try to avoid or escape from, while a reward is considered to be something we would like to approach or obtain. These instrumental reinforcers serve as goals for behavioral actions that lead to the desired outcome. This model aligns closely with Konorski's "biphasic model" and Dickinson & Dearing's "motivational" ideas, as well as with Lazarus' (2021) definition of emotion, in which events are likewise categorized as desirable or undesirable based on their relevance to personal goals and well-being.

Complementary evidence for this motivational framework comes from the Osgood, Suci, and Tannenbaum (1957) research who demonstrated that emotional labels are primarily distributed along a bipolar dimension of affective valence, ranging from pleasure (attraction) to displeasure (aversion). This valence dimension is often complemented by a second dimension of arousal, reflecting the intensity of physiological and behavioral activation.

This dimensional perspective was further formalized by Russell's (1980) "the circumplex model" of emotion, which organizes emotions within a two-dimensional circular space defined by valence and arousal (*Figure 2A*). In this framework, valence refers to the emotional pleasantness of a stimulus, whereas the concept of arousal is defined as the level of physiological activation or the intensity of behavior (Eysenck, 1975; Straub et al., 2020). In this model, any emotion can be represented at varying levels of valence and arousal, or at neutral levels of one or both dimensions. For example, low valence combined with high arousal corresponds to unpleasant emotions, such as fear or distress, while the center of the circle represents neutral valence and moderate arousal. Moreover, Bradley, Greenwald, Petry, and Lang (1992) proposed the vector model of emotion (*Figure 2B*), which refines the circumplex model. This model assumes an underlying arousal dimension, with valence determining the direction of a specific emotion. Unlike the circumplex model, the vector model predicts that valence varies little at low arousal levels, whereas the valence range expands with increasing arousal, in other words, high arousal-neutral emotions do not occur (Bradley et al., 1992).

Importantly, the dimensional model of emotion and motivational framework are not only compatible but also they are increasingly becoming integrated within recent views of attentional control. As discussed in the previous chapter (*Chapter 2. Section 3*), the brain maintains a spatial priority map that is continuously shaped by selection history. Within this history, stimulus value plays a crucial role, as it enables the accumulation of information regarding stimuli that have been previously associated with reward or punishment (Anderson et al., 2021).

The dimensional approach complements this framework by specifying the affective properties that underlie stimulus value, namely, valence and arousal (Brosch, Pourtois, & Sander, 2010). These dimensions do not simply characterize emotional stimuli, rather, they provide the basis through which learned stimulus-outcome associations are encoded and expressed as attentional priorities within the attentional priority map (Anderson et al., 2021). For instance, a stimulus does not capture attention because it was once rewarded; it captures attention because the experience of reward has resulted in the assignment of high positive valence and elevated arousal, and it is those affective properties that elevate its position on the priority map (Failing, & Theeuwes, 2018). This relationship between learned associations with outcomes and priority of processing is best represented by the arousal dimension. Stimuli that elicit high levels of arousal, regardless of whether their intensity derives from emotional content or from reward history, consistently produce greater and more persistent capture than those characterized with lower levels of arousal (Carretié, 2014). In essence, arousal is the dimension that determines the magnitude of that capture, regardless of whether the priority was acquired through phylogenetically old emotional circuits (Blanchette, 2006; Vuilleumier, 2005) or through learning history (Abado et al., 2023). Taken together, the value-driven theory provides the empirical evidence that learned associations with outcomes shape attention, while the dimensional approach provides the theoretical dimensions that explain why these associations result in prioritized processing.

In contrast to dimensional and motivational approaches, other theories have attempted to classify emotions into discrete categories. For instance, Ekman (1984) proposed one of the most influential frameworks for understanding emotions, identifying a set of basic emotions with universal physiological and behavioral signatures. Ekman highlighted six facial expressions that are thought to be universal across all human cultures: fear, anger, sadness, happiness, surprise, and disgust.

Similarly, Panksepp (1989, 1998) proposed a set of primary emotions: seeking, rage, lust, panic, play, care, and fear. Unlike Ekman's, Panksepp's classification stems from his observation of animal behavior, and Panksepp treats emotions as fixed action patterns elicited as motor responses to stimuli (Panksepp, 1989; Rolls, 2014). Later, this list was refined, and only five of these are generally considered primary emotions by researchers: anger, fear, disgust, sadness, and happiness, while emotions such as guilt and jealousy are considered complex emotions, resulting from the combination of multiple basic emotions (Bowers, Dietz, & Jones, 2014).

Taken together, these theoretical perspectives converge on the idea that emotions are not merely subjective feelings but are fundamentally motivational states that organize perception, attention, and action. Emotional experience reflects the interaction of "appetitive", "pleasure", "attraction" and "aversive", "unpleasure", avoidance" motivational systems operating across varying levels of

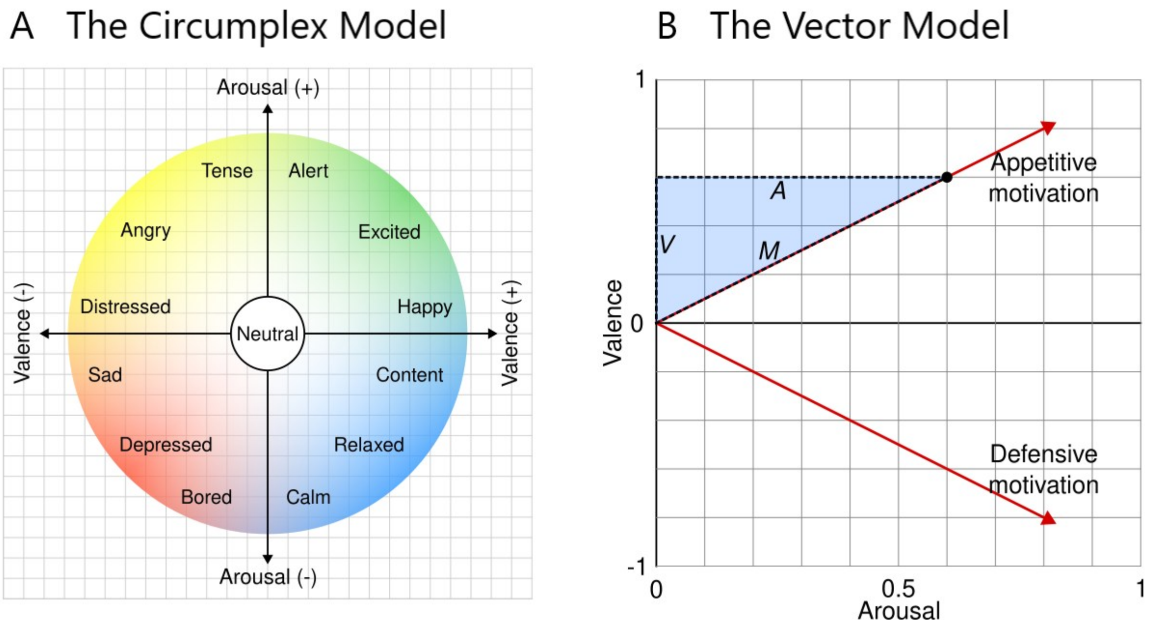


Figure 2. a) Russell's circumplex model of affect (1980), which represents emotions along two continuous dimensions: valence (pleasant–unpleasant) and arousal (calm–alert); b) Bradley et al.'s vector model of emotion (1992), which conceptualizes emotions as vectors showing how arousal varies with valence, emphasizing stronger arousal for more extreme (positive or negative) emotions.

arousal. By conferring motivational significance to stimuli, emotions bias cognitive processing and prioritize information that is relevant for adaptive behavior, an idea that is central to the present investigation of emotional influences on attentional selection.

Because the aim of the present study is not to precisely define or categorize emotions, I consider the dimensional and/or motivational approaches to be more inclusive and flexible for studying attentional mechanisms, particularly when treating emotion as a form of salience that biases perception and attention. Furthermore, after careful consideration of the inherent subjectivity of human emotions, their investigation becomes particularly challenging. Ultimately, I came to understand that, although uncertainty still surrounds the classification and variability of basic emotions, one aspect remains consistent across them: emotions are generally experienced as either positive or negative and carry motivational significance for survival.

Even within negative emotions, such as fear, disgust, or sadness, there is considerable overlap in underlying neural and behavioral mechanisms (Gainotti, 1989). Thus, when referring to a negative emotion such as fear, it is assumed that it may encompass elements of other negative emotional states. In the context of the present work, a stimulus is defined as negative when it is perceived as aversive, undesirable, harmful, unpleasant, or something to be avoided. Importantly, the negativity of the images used in this study is determined by subjective, scale-based ratings and does not necessarily correspond directly to specific neural signatures.

Finally, the decision to focus on negative rather than positive emotional stimuli is motivated by the robust evidence that negative events are generally more potent, more salient, and exert stronger and more pervasive effects on cognition and behavior (Lazarus, 2021). As such, negative stimuli provide a particularly powerful tool for investigating how emotional salience interacts with attentional selection and control.

2. EMOTIONAL STIMULI AND ATTENTIONAL DEPLOYMENT

Several studies highlighted the bidirectional interaction between emotion and attention (Öhman et al., 2001; Armony & Dolan, 2002). This dynamic interplay operates in both directions: emotional input (whether negative or positive) influences behavior through attentional mechanisms, while changes in behavior can, in turn, modulate the orientation of attention toward emotional stimuli (Kostandov, 1975; Pessoa, 2010, 2013; Brosch et al., 2013). Yet, it remains unknown whether attentional control acts differently when encountering emotional versus non-emotional inputs.

A key distinction concerns whether this interaction occurs automatically or can also be controlled. Automatic information processing refers to the rapid, reflexive, and involuntary responses to sensory input (Olsson & Öhman, 2009). This form of processing is considered exogenous rather than the result of deliberate, top-down control, and it typically emerges when the system must quickly select relevant information among multiple competing stimuli (Cohen, Mallow, Jenkins, & Paul, 2014). The widely accepted view holds that emotional stimuli, especially those carrying negative valence, capture attention automatically, guiding attentional allocation in what is generally characterized as a "preattentive" or bottom-up manner (Öhman, 1997). The strong impact of negative stimuli on attentional control is often attributed to evolutionary reasons, as such stimuli carry high survival value and therefore generate salient signals (LeDoux, 2008; Padmala, Sambuco, & Pessoa, 2019). From this perspective, the capacity to rapidly detect potential threats in the environment constitutes an adaptive mechanism that enhances self-preservation (Levi, 1975; Rolls, 2014). Consequently, the detection of threat-related stimuli needs to operate independently of selective attention, which is typically assumed to be slow, effortful, serial, and voluntary processes associated with conscious perception. Threat-related stimuli, instead, assumed to evoke rapid, parallel, and automatic preattentive processing (*see chapter 2, section 2*), enabling the detection of potentially threatening information even outside the current focus of attention (Öhman, 1997). However, there exists an alternative theory suggesting that, while the initial sensory enhancement in the visual cortex operates as an all-or-nothing mechanism to ensure rapid detection of threatening stimuli compared to neutral ones, the subsequent cognitive processing and categorization involve more flexible, gradual, and context-dependent evaluation (Carretié et al., 2025; Xue & Pourtois, 2025; Brosch, Pourtois, & Sander, 2010). Through the amplification of the neural response to emotionally significant stimuli, this mechanism ensures that such stimuli prevail in the competition for attentional resources, making them harder to ignore than neutral stimuli (Carretié, 2014). Consistent with this view, Breitmeyer and Ganz (1976) reported that the attentional capture is mediated by an "early warning system" that directs attention toward objects and locations of potential significance. As a result, negative information (e.g., fear-related stimuli) is especially potent in capturing involuntary attention and is processed rapidly through adaptive mechanisms (Pessoa, 2013). Hoffman (1997) emphasized that the elicitation and modulation of the involuntary (defensive) response to sudden stimuli are not immune to experience-dependent factors such as learning, nor to the influence of attentional processes. When a stimulus is aversive, it typically leads to an increase in physiological arousal. In such cases, mechanisms related to self-preservation or forewarning may exert their primary effects by regulating or attenuating arousal levels, rather than by directly altering the afferent sensory input generated by the stimulus itself. In short, attentional capture by negative stimuli relies highly on automatic processing mechanisms (Dolan & Vuilleumier, 2003) that operate independently of voluntary attentional control, and attention is frequently biased toward this negative information, leading to a preferential orienting of attention toward threat-related or unpleasant stimuli (Matthews & Wells, 1999; Trippe et al., 2007; Grégoire et al., 2018; Öhman, 1997).

Attentional capture by emotionally salient stimuli has been demonstrated under a wide range of challenging conditions, including crowded displays, visual masking, and situations in which the stimulus is task-irrelevant, or its influence is unintended. Across these contexts, findings consistently show that emotionally salient stimuli receive priority in information processing over neutral stimuli (Öhman & Öhman, 2009; Öhman et al., 2001; Kastandov, 1975; Phelps, Ling, & Carrasco, 2006; Choi, Padmala, & Pessoa, 2012; Lim, Padmala, & Pessoa, 2008; Carretié et al., 2025).

Emotion can either enhance or impair performance, which is largely based on the task's relevance and the level of arousal (Pessoa, 2010, 2013; Padmala, Sambuco, & Pessoa, 2019). For instance, Pessoa and colleagues (2012) asked participants to perform a simple discrimination task in which they had to respond to face stimuli and withhold their response when the stop signal appeared. They found that response inhibition was enhanced when fearful faces were presented compared to neutral faces, but only under low-arousal picture conditions. When arousal levels were high, the performance was impaired (Padmala, Sambuco, & Pessoa, 2019). They claimed that this impairment reflected a reduction in the cognitive resources available for effective response inhibition, and as a consequence, attentional control prioritized the processing of high-arousal items (Lim, Padmala, & Pessoa, 2008; Choi, Padmala, & Pessoa, 2012). Similarly, Kostandov (1975) reported that when participants needed to recognize neutral and negative (unpleasant) words, they showed better performance in recognizing negative words than neutral ones.

Although emotionally salient stimuli capture attention automatically, their lasting impact highly depends on prior exposure. For example, Ferrari, Bradley, Codispoti, and Lang (2011) showed that motivational relevance is also a crucial determinant of attentional prioritization, and this relevance can change with repeated exposure, thereby modulating attention allocation (Codispoti et al., 2016; Grimshaw et al., 2018). In other words, when a negative stimulus is encountered repeatedly, it is assumed to lose its motivational salience and consequently no longer receives prioritized processing.

Another important factor is individual differences in responses to emotional stimuli. Individuals differ in their emotional reactions to stimuli that were previously neutral (Barnacle et al., 2018). Through experience, certain events or objects can acquire emotional significance, leading to heightened behavioral responses (Antony & Swinson, 2000). For instance, Trippe et al. (2007) compared behavioral responses to task-irrelevant phobia-related stimuli versus neutral stimuli in spider-phobic and control participants using an attentional blink task. Their findings showed that people with phobia detected phobia-related objects (e.g., spiders) more quickly and more often than neutral stimuli. This suggests a prioritization of emotionally salient information and an earlier identification of fear-related stimuli compared to neutral ones. Moreover, Williams, Watts, MacLeod, and Mathews (1988) demonstrated similar findings among clinically anxious individuals. Their results indicated that clinically anxious participants automatically oriented their attention toward threatening stimuli, and they were not only allocating their attention more rapidly to negative than to neutral information, but also they showed greater difficulty in disengaging from such stimuli (Armstrong & Olatunji, 2012; Brosch et al., 2013).

In conclusion, one thing that is probably common among humans and animals is the tendency to exhibit a biased attentional shift in the presence of a threat (Eysenck, 1975; Öhman, 1997). This attentional bias is characterized by a rapid orientation toward negative stimuli, accompanied by heightened arousal, which together facilitate the faster detection of potential threats to survival (Cisler & Koster, 2010; Morel et al., 2014). These results further indicate the crucial role of prior experiences in shaping how emotionally salient stimuli capture attention.

3. TASK-IRRELEVANT EMOTIONAL INFORMATION PROCESSING

In light of the prior findings, it is clear that emotional stimuli capture attention in a bottom-up manner and trigger automatic responses more potently compared to stimuli with no emotional value (Pessoa, Kastner, & Ungerleider, 2002; Codispoti et al., 2016; Öhman et al., 2001; Carretié, 2014; Xu et al., 2023). Particularly, negative stimuli are prioritized in information processing (Brosch, Pourtois, & Sander, 2010). These adaptive mechanisms of orienting attention toward emotional stimuli may lead to poorer performance when these stimuli are irrelevant to the task at hand, acting as powerful distractors (Ferrari, Canturi, & Codispoti, 2022). Indeed, it has been demonstrated that the presence of a negative stimulus in a display result in longer reaction times to target stimuli compared to neutral stimuli (Pessoa, 2013; Codispoti et al., 2016; Ferrari et al., 2011; Grimshaw et al., 2018; Murphy et al., 2020).

There is an ongoing debate regarding whether and how distraction caused by emotional stimuli is controlled. These perspectives primarily differ in when and how attentional resources are allocated. On the one hand, salient signals are assumed to be actively suppressed at early stages of visual processing (Sawaki & Luck, 2010), so that emotional distractors receive progressively fewer attentional resources. In this case, proactive control mechanisms can effectively regulate attentional capture by salient distractors (Xu, Theeuwes & Los, 2023; Grimshaw et al., 2018), by suppressing the likely distractor location prior to display onset. These findings may suggest that the reduction of emotional distractor interference may be mediated, at least in part, by spatial inhibition, such that any stimulus appearing in the high-probability distractor location is suppressed. On the other hand, some findings indicate that emotional distractors, like physically salient distractors, initially capture attention and are only subsequently suppressed (Theeuwes, 2010), in other words, attentional resources are initially allocated to the distractor before suppression takes place.

Xu and colleagues (2023) aimed to examine these two accounts and to clarify whether emotional distractors capture attention before suppression. Within a classic visual search task, they induce participants to adopt either a singleton-detection mode or a feature-search mode. Their results indicated that initial attentional capture is not mandatory for suppressing emotional distractors. Importantly, the effectiveness of suppression was strongly dependent on the predictability of the salient distractors, with attentional resources allocated to these stimuli varying according to their expected occurrence.

In visual search studies, the predictability of emotional distractors is commonly manipulated either by presenting a prior cue that signals the features of the upcoming distractor (e.g., Chao & Lee, 2019; Johnen & Harrison, 2019) or by increasing the frequency with which emotional distractors appear (e.g., Grimshaw et al., 2018; Harris & Pashler, 2004; Zhao & Most, 2019). Similarly, Codispoti et al. (2016) investigated how emotional interference on behavior varies with repeated presentations of the same emotional distractors. Starting from the assumption that emotional stimuli are prioritized by the attentional system and processed in a mandatory fashion (Codispoti et al., 2016; Ferrari et al., 2011), they examined whether such stimuli lose their priority after repeated presentation when they are irrelevant to the task. They found that emotional stimuli became less distracting after only a few repetitions, suggesting that attentional capture by emotional stimuli is subject to modulatory influences (Harris & Pashler, 2004). Later, Codispoti and colleagues (2016) aimed to provide further insights into the repetition effect of emotional stimuli. Participants performed a parity judgment task, deciding whether pairs of digits had the same or different parity, while emotional and neutral pictures were presented as distractors. The task included habituation blocks, in which the same stimuli were repeated, and novel block, which presented new images. They observed that participants responded more slowly to emotional stimuli compared to neutral ones only in the first habituation block and in the novel block, indicating that the emotional stimuli were distracting primarily when novel. They argued that the observed decline in emotional interference across repetitions was stimulus-specific, driven by repeated exposure to the same pictures during the habituation block, rather than reflecting a general inhibition of emotional stimuli (Codispoti et al., 2016). Interestingly, neural measures reflected a different scenario. Even after repetition, emotional pictures continued to elicit larger Late Positive Potentials (LPPs) than neutral ones, suggesting that emotional stimuli retain a special status for attentional resources even when behavioral interference is reduced (Ferrari et al., 2011). Furthermore, Micucci and colleagues (2020) provided further evidence that habituation cannot be the only explanation for the reduced attentional capture observed with emotional distractors. Using different pictures as distractors, they showed that the decline in attention allocation to emotional stimuli is also influenced by the overall frequency of distractor presentation.

In addition, it has been demonstrated that the control of emotional distractors also depends on the availability of attentional resources (Shafer et al., 2012). Distractors capture attention only when there are sufficient resources to process stimuli beyond those that are task relevant. When attentional demand is high, fewer resources remain to process irrelevant information, and as a consequence, interference from such information is successfully eliminated (Thyagaraj &

Padmala, 2025). On the contrary, under low attentional demand, automatic processing of emotional stimuli can occur. These assumptions are consistent with the “perceptual load theory” (Lavie, 1995), which posits that attentional capture depends on the perceptual load of the task at hand. Similarly, Yates, Ashwin, and Fox (2010) provided supporting evidence for this theory, showing that under high perceptual load, even highly salient fear-related faces did not produce interference. However, other studies have shown that the effect is not conclusive (Müller, Andersen, & Keil, 2008; Hind-Attar & Müller, 2012): even under high-demand task conditions, emotionally arousing pictures (i.e., negative) continued to capture attentional resources, resulting in slower responses, more errors, and delayed disengagement from negative stimuli.

In conclusion, the main aim of the present study was to investigate the special status of emotional distractors and to examine whether attentional capture by these stimuli can be modulated through statistical learning. Specifically, we sought to determine how emotional distractors compete with targets for visual processing resources and whether spatial regularities of distractors or repeated exposure to negative stimuli can reduce their overall disruptive impact. Overall, this work provides insight into the interplay between emotional salience and learning-dependent attentional control, highlighting the conditions under which emotional stimuli can be effectively suppressed or continue to modulate attentional selection.

Chapter 4: METHOD

GENERAL METHOD

The project was approved by the ethical committee of the University of Verona, with the reference number CARP # 05.R1_2024.

All experiments of this project were designed using OpenSesame Software 3.3.14 (Mathôt, Schreij, & Theeuwes, 2012), and stimuli were presented on a 17-inch CRT monitor screen with 1920 x 1080 resolution against a black background. The refresh rate of the screen was 60 Hz. Participants were tested in a dimly lit room, and the viewing distance was held constant at 57 cm during the whole experiment using a chin rest.

To answer our questions, this project included three behavioral experiments. In the first experiment, our aim was to create a picture dataset, consisting of neutral and negative images, to use in the following experiments. In the second experiment, we examined the degree to which emotional distractors could be attentionally suppressed using a visual search task. Finally, in the third experiment, we investigated the effect of statistical learning on location-specific distractor suppression. In the second and third experiment, the same visual search task was used to evaluate whether attention was biased toward salient stimuli.

All three experiments utilized the SR Research Ltd. Eyelink 1000plus eye-tracker, featuring a spatial resolution of 0.2° or better, to ensure that participants maintained their fixation at the center of the display throughout the entire experimental session. The sampling rate of the eye-tracker was set to 1000 Hz. Before each experimental session, 9-point calibrations were implemented.

All analyses were performed using R (4.5.1). Firstly, trials with saccades and eye fixation falling beyond 2° from the fixation cross were detected and removed before proceeding with further analyses (for details of the analyses, see below). Participants with saccades in more than 15% of the total trials were excluded from the analyses. The final analyses were performed on the remaining participants and trials in terms of mean ratings of each picture in experiment 1 and on performance, in terms of error rates and reaction times (RTs), in experiments 2 and 3. Participants with accuracy below 70% were excluded from the final sample before computing further analyses. In addition, in experiments 2 and 3, the inverse efficiency score (IES) was computed and analyzed. IES is a combined measure of accuracy and RT that provides an index of overall task efficiency, allowing a more comprehensive comparison of task performance across experimental conditions (Townsend & Ashby, 1983). It is calculated by dividing the mean RT by the proportion of correct responses (RT/accuracy), with lower IES values indicating higher performance efficiency and reflecting faster and more accurate responses. It is essential to note that the IES analyses were conducted solely to provide additional insight into potential speed–accuracy trade-offs. In such experiments, correlated outcomes between RT and error rate are expected (Bruyer & Brysbaert, 2011).

1. EXPERIMENT 1:

PERIPHERAL EMOTIONAL PICTURE STANDARDIZATION

Since attention is limited and eyes cannot be simultaneously directed toward multiple stimuli, most of the information in our environment falls outside the foveal area (i.e., periphery) (Helmholtz, 1871, as cited in Wright & Ward, 2008). Nevertheless, it is crucial to be able to extract the necessary information from outside of the fovea and make preliminary judgments before overtly orienting attention toward it. Even though attention is initially assumed to coincide with gaze direction, studies have shown that the focus of attention can shift independently of ocular fixation (Wright & Ward, 2008). While visual acuity is highest within the foveal area, this clarity decreases progressively with distance from the center of fixation (James, 1890).

Detection of peripheral information is crucial for emotional stimuli, which must often be detected even in the periphery to trigger adaptive behavior (De Cesarei, Codispoti, & Schupp, 2009). Indeed, previous research has shown that the evaluation of emotional information differs when it is presented in the periphery compared to the fovea, with peripheral vision contributing significantly to information processing (Wright & Ward, 2008).

Our objective, therefore, was to ascertain that emotional information processing would be adequate also in peripheral vision, given that in subsequent experiments emotional stimuli were to be presented peripherally. Several studies have demonstrated differential processing of emotional pictures depending on their position within the visual field (Yegiyan & Lang, 2010; De Cesarei et al., 2009; Calvo, Avero, & Nummenmaa, 2011). For instance, emotional pictures presented in the periphery at 8.2° of eccentricity were processed less efficiently compared to those shown foveally, with this decrease in efficiency correlating with reduced recognizability (De Cesarei et al., 2009).

Similarly, Calvo and colleagues (2011) found that both accuracy and RTs in emotional picture discrimination worsened when stimuli were presented 5.2° into the periphery. Significantly, performance is impaired more for affective (valence-based) than for semantic categorization tasks in peripheral viewing conditions, which shows that visual information processing varies not only according to the eccentricity of stimulus presentation but also between affective and semantic dimensions.

Given these findings, we reasoned that it would be inappropriate to simply select images from standardized databases, typically validated under foveal presentation, and use them in paradigms requiring peripheral presentation. For this reason, our primary goal was to select stimuli that, shown in the near periphery of the visual field, would match in terms of semantic content and visual complexity while differing in affective category, thereby ensuring appropriate control for the subsequent experiments.

1.1. Participants

A total of 20 (17 females; mean age ± SD, 25.55 ± 3.4) participants took part in this experiment; however, two participants were excluded from the final sample, one due to not completing the entire experiment and the other due to excessive eye movements (above 50%). All participants (15 females; mean age ± SD, 25.7 ± 3.5) had normal or corrected-to-normal vision, and they received fixed monetary compensation (20 euros) and gave written informed consent before participation.

1.2. Picture Dataset

The pictures were selected from the following sources: Open Affective Picture Database (OASIS: Chen et al., 2020), International Affective Picture System (IAPS: Lang, Bradley, & Cuthbert, 1997), EMOPICS (Wessa et al., 2010), THINGS (Hebart et al., 2019), Geneva Affective Picture Database (GAPED: Dan-Glauser & Scherer, 2011), and free-to-stock images on the internet.

Figure 3: Illustration of the Example Salient Stimuli Used in the Experimental Paradigm

All pictures were equated in luminance and contrast using MATLAB Shine Color Toolbox (SHINE color toolbox: Dal Ben, 2023; SHINE toolbox: Willenbockel, Sadr, Fiset, Horne, Gosselin, & Tanaka, 2010), which is a toolbox that takes full advantage of the functions from the

SHINE toolbox for controlling low-level properties of colorful images. The color salience of the distractors was determined based on the distance between colors in the CIELab color space, while maintaining identical luminance. The CIELab color space includes lightness (L), red and green (A), and blue and yellow (B) channels, and while A and B channels are kept constant, not manipulated, the L channel is rescaled.

Another important aspect of the analysis involved the semantic categorization of the picture stimuli. We observed that the negative picture datasets predominantly contained images of people, such as mutilated bodies, injuries or diseases, whereas the neutral datasets consisted mostly of objects or landscapes. This discrepancy made it essential to match the semantic categories of distractors when defining our final dataset. Moreover, the negative pictures raised further concerns regarding their ambiguity and high visual complexity, which make it challenging to pair them appropriately with neutral social stimuli. Neutral social pictures most commonly depict one or more people in well-defined, easily interpretable contexts and showing complete body parts. In contrast, social negative pictures often depict mutilated body parts, which tend to present small, fragmented scenes with greater visual complexity. Considering these factors, creating a standardized set of neutral and negative distractor stimuli required careful attention to matching complexity, avoiding overly ambiguous images, and diversifying the selection of pictures. To address these issues, we divided the main dataset into four semantic categories: “neutral social,” “neutral non-social,” “negative social,” and “negative non-social”. Social category refers to pictures containing a human agent (e.g., a human body part, a group of people). Importantly, these pictures did not include close-up face captures. The non-social category refers to pictures that do not contain any human agent (e.g., animals, objects).

1.3. Design and Procedure

In this experiment, participants were asked to rate a total of 696 pictures on four dimensions: Valence, Arousal, Complexity, and Recognizability. *Valence* was defined as the emotional value of the picture, ranging from negative (unpleasant) to positive (pleasant), with lower ratings indicating more negative emotions. *Arousal* referred to the degree to which a picture provoked an emotional response, regardless of whether the emotion was positive or negative, ranging from calm to excited. *Recognizability* was defined as the extent to which participants could clearly understand the context of a picture, while *Complexity* referred to the number of visual elements or the overall perceptual density within the picture, both of which ranged from low to high. Valence and Arousal ratings were used together to classify pictures as either negative, neutral, or positive in terms of affective (emotional) content, whereas Complexity and Recognizability were considered complementary dimensions to define the interpretability (e.g., elaborateness or visibility) of the picture. Specifically, we expected that higher picture complexity would be associated with lower recognizability. Furthermore, we anticipated that higher negativity would be associated with higher arousal (Scherer, 2000; Gainotti, 1989; Bradley & Lang, 1994).

Each trial started with a self-paced eye drift check using a small white dot. Once participants were fixated on the center of the display, a white fixation cross appeared for 500ms at the center of the display against a black background. The fixation cross was followed by a picture display, in which a picture (6.5° x 6.5°) from the dataset was presented, either to the right or to the left of the fixation cross, 7° away from fixation. The order of presentation of the pictures was randomized across the whole experiment. The pictures were presented for one second. The presentation of the pictures was followed by four 9-degree Likert scales, presented in the same order for all trials and participants: Valence, Arousal, Complexity, and Recognizability. Participants were asked to respond using the numbers on the keyboard (*Figure 4*). Each scale remained on the display until a response was given.

As previously mentioned, the key objective here is to assess pictures in terms of Valence, Arousal, Complexity, and Recognizability, when presented in the periphery.

1.4. Data Analysis

Trials with eye movements were detected and removed from the final analysis. After the exclusion, all pictures received a minimum of 10 and a maximum of 18 votes (mean vote number ± SD, 15 ± 1.6).

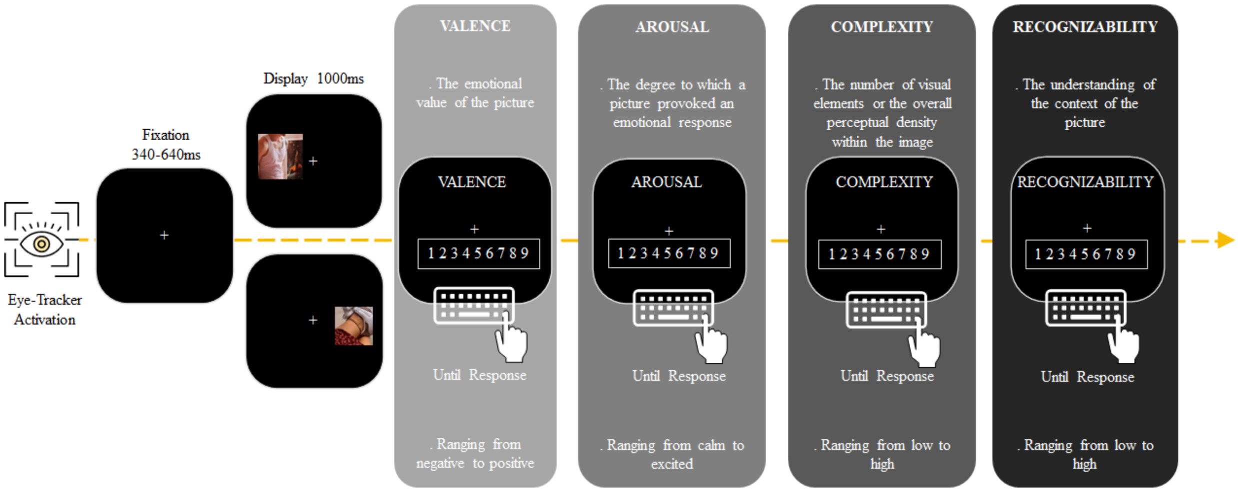


Figure 4. Experimental design of Experiment 1. Each trial began with the activation of the eye tracker, and once participants fixated at the center of the display, a fixation cross appeared for a random duration. A picture from the dataset was then presented either to the right or left of the fixation cross at a distance of 7 ° from the center. After one second, the Valence, Arousal, Complexity, and Recognizability scales appeared in sequence, and participants were asked to provide their ratings using the number keys on the keyboard.

Our primary objective was to create three distinct datasets to serve as distractors (neutral and negative) and fillers (neutral). Therefore, we defined inclusion criteria for negative and neutral affective (valence) pictures. Considering a rating of 5 as a neutral reference point on the Likert scale, we included neutral pictures (both for distractors and fillers) that fell within a limited range of values around the reference point. Specifically, pictures with ratings between 3.8 and 6.2 were selected initially. A similar calculation was performed for negative pictures, assuming that 1 represents the most negative reference point on the scale and including pictures' ratings between 1 and 3.2. All the other pictures, which fell between 3.2 and 3.8 or above 6.2, were excluded because they were considered ambiguous or positive. Furthermore, pictures were selected according to the match between complexity and recognizability ratings.

1.5. Results

Potentially negative animal pictures (e.g., snakes, spiders, dead animals) were categorized as neutral, along with pictures representing float, forest fires, etc. (Mean valence rating ± SD, 4.8 ± 1.5), indicating that fearful animal pictures, when presented in the periphery, were not perceived as negative as in previous subjective assessment experiments. Consistent with Calvo and colleagues (2011), affective categorization appears to be more disrupted by peripheral presentation than semantic categorization.

Finally, a total of 444 pictures were selected to use for the following experiments: 91 for the *negative social distractor dataset* (valence rating M ± SD, 2.08 ± 0.46; arousal rating M ± SD, 4.5 ± .66; complexity rating M ± SD, 4.4 ± .9; recognizability rating M ± SD, 6.5 ± 1.01), 91 for the *neutral social distractor dataset* (valence rating M ± SD, 5.23 ± 0.47, arousal rating M ± SD, 2.9 ± .54; complexity rating M ± SD, 4.5 ± 1.05; recognizability rating M ± SD, 6.5 ± 1.01), and 262 for the neutral, both social and non-social, filler dataset (valence rating M ± SD, 5.3 ± 0.48, arousal rating M ± SD, 2.7 ± .53; complexity rating M ± SD, 4.1 ± 1.1; recognizability rating M ± SD, 6.7 ± 1.33) (for the further details on rating, *see Figure 5*; for selected picture coding and descriptions, *see appendix*). Through the complexity rating, we ensured that the perceived complexity of the pictures was matched between neural and negative stimuli.

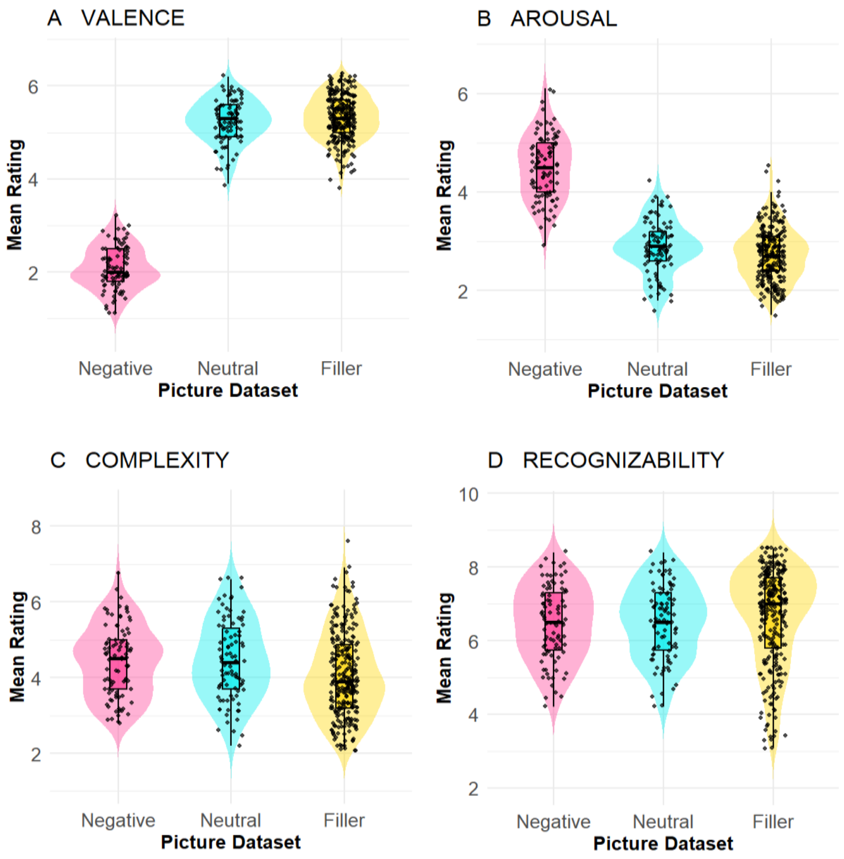


Figure 5: Mean Ratings for the pictures across different dimensions: a) Valence scale, b) Arousal scale, c) Complexity scale, d) Recognizability scale

2. EXPERIMENT 2:
CAN ANY KIND OF SALIENT STIMULI BE SUPPRESSED?

2.1. Participants

A priori power analysis was done, using G*Power 3.1 analysis software (Faul, Erdfelder, Buchner, & Lang, 2009), to determine the necessary sample size. Since this is one of the first experiments that uses complex pictures as a distractor, presented in the periphery, within the visual search paradigm, we had to use a two-step procedure.

First, we reviewed the existing literature that examined the effects of salient distractor presence (i.e., color singletons) on attention (De Tommaso & Turatto, 2019), with a task similar to the current study. A significant main effect of distractor presence in the additional singleton search task was reported, with a very large effect size of $\eta^2_p = .560$ ($f = 1.13$), requiring a minimum of 8 participants to achieve a power of 0.95. Since the presence of a salient distractor typically produces a robust behavioral effect, a relatively small number of participants is often sufficient to detect the distractor cost.

However, in the current experiment, emotional pictures were used as salient distractors. To our knowledge, no previous study has employed complex emotional pictures within a visual search paradigm in which the target and distractors share the same visual dimension, as well as presented in the periphery. Therefore, we considered a second study that investigated the effects of peripheral emotional distractors (negative, neutral, positive) in a similar task and reported a partial eta-squared of $\eta^2_p = .136$. This corresponds to Cohen's $f = 0.40$ and reflects a medium-to-large effect size (Grimshaw et al., 2018). A power analysis ($\alpha = .05$, power $= .80$) indicated that a sample size of approximately 25 participants would be adequate to detect an effect of this magnitude in the current study.

To ensure adequate power for both types of effects, especially for the more demanding distractor-related effect, we decided to test a minimum of 25 participants, assuming that this sample size would be sufficient to obtain reliable and generalizable results.

A total of 31 (22 females; mean age ± SD, 22.4 ± 3.6) participants took part in this experiment; however, four participants were excluded from the final sample due to accuracy below 70%. After exclusions, 28 participants (19 females; mean age ± SD, 22.6 ± 3.8) remained, which is above the recommended sample size for detecting medium-sized effects and therefore provides sufficient statistical power. All participants had normal or corrected-to-normal vision, and they received fixed monetary compensation (15 euros) and gave written informed consent before participation.

2.2. Design and Procedure

The experiment consisted of a 19-trial practice phase followed by an experimental phase, comprising 960 trials, divided into six blocks. In the practice phase, incorrect or too-late responses elicited audio feedback. No auditory feedback was provided during the experimental phase.

In the experimental phase, a distractor was present on 60% of trials. The distractor-absent condition included 160 trials for each display type (pictures and colored squares). In the distractor-present condition, trials were categorized according to the distractor type: neutral, negative, red or green color salient distractor (144 trials per type). Additionally, probe distractor-absent trials were included (16 trials for each condition: target unique color red, green, target unique picture neutral,

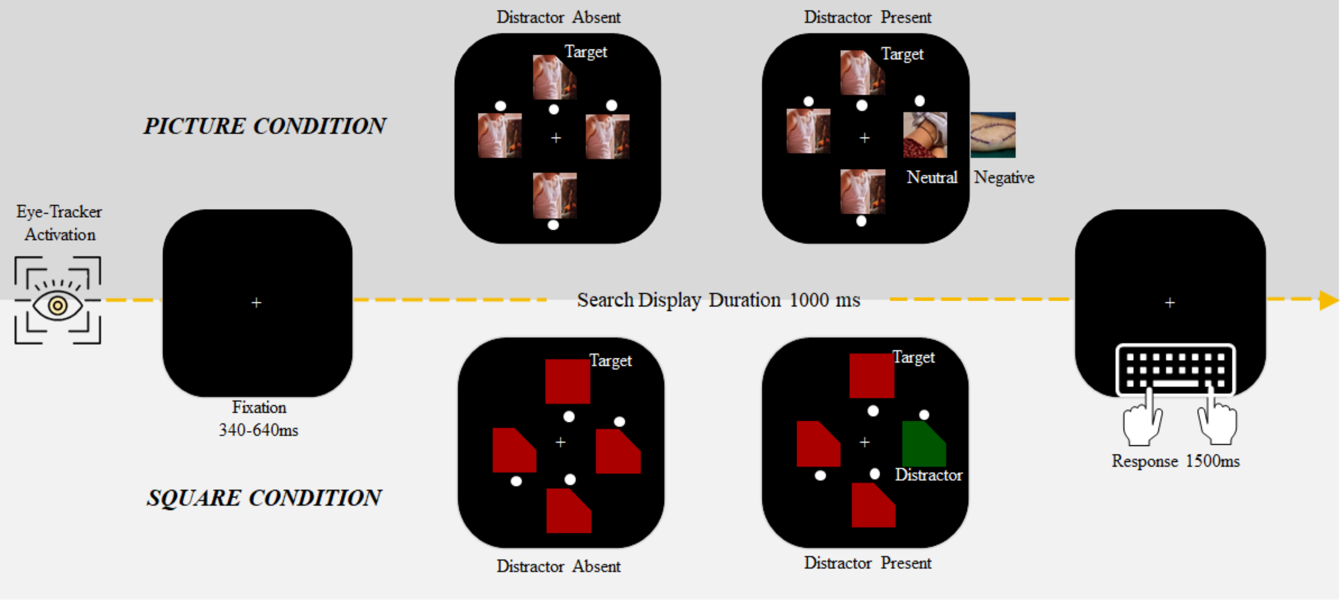


Figure 6. Experimental design for Experiments 2 and 3. Each trial began with the activation of the eye tracker, and once participants fixated at the center of the display, a fixation cross appeared for a randomized duration between 340 and 640ms. Four stimuli were then presented, evenly spaced around an imaginary circle at a distance of 7° from the fixation cross. Participants were asked to locate the target, which had a distinct outline shape, and indicate whether the white dot appeared above or below it. Displays included either simple geometric shapes or pictures, and a salient distractor was present in 60% of the trials.

and negative). In these trials, the target was a unique stimulus, differing both in form and, in some cases, in color or emotional valence, while no distractor was present.

Each trial started with the activation of the eye-tracker and the presentation of a small white dot at the center of the display for fixation calibration. Once participants fixated stably on the dot, a white fixation cross was presented for a randomized duration between 340 and 640ms. The search display then appeared for 1000ms. On each trial, the search display consisted of four stimuli (either colored squares or pictures; 6.5° x 6.5°), evenly spaced around an imaginary circle at a distance of 7° from the fixation cross. The target was defined as the item with a different outline shape, either the only intact image (or square) among those with a cut above, or the one with a cut above among the intact ones. In 60% of the trials, a distractor was present. In the color singleton condition, the distractor was a red square among green squares or vice versa (50% probability). In the picture condition, the distractor differed in terms of emotional valence, being either a unique negative or a neutral picture among other neutral pictures (50% probability). Additionally, each stimulus had a white dot (0.8°) positioned randomly above or below it. All possible combinations of the position of the dot and the display type occurred equally often. Each picture stimulus appeared a minimum of once and a maximum of two times throughout the experiment. Participants were instructed to search the display for the stimulus with a different outline shape (the target) and indicate whether the white dot appeared above or below it by pressing the "Z" or "M" key. After the search display offset, participants had an additional 1500ms to respond. Intertrial interval was 100ms (*Figure 6*).

2.3. Data Analysis

Participants with a mean accuracy below 70% were excluded. RTs were analyzed after excluding trials with wrong responses and RT below 200ms. Furthermore, trials in which RT fell outside ± 2.5 SDs from the mean value for each participant (on average, less than 1% of the data) were excluded. Analyses were performed on performance in terms of accuracy and reaction times (RTs) once the exclusion criteria were applied. Repeated Measures Analysis of Variance (ANOVA) was performed on error rates and RTs. When appropriate, p-values for statistical significance were adjusted for multiple comparisons (Holm-Bonferroni correction). Along with significance levels, estimates of effect size were calculated for each analysis (η^2_p and Cohen's d; for a discussion, *see* Nakagawa & Cuthill, 2007).

The use of IES allowed us to capture a more integrated measure of task performance, reflecting the balance between response speed and accuracy. Unlike RTs or error rates alone, the IES provides a unified indicator of processing efficiency, thereby offering a more sensitive measure of how the presence of distractors influences participants' ability to maintain efficient performance.

2.4. Results

Eye-tracking data were analyzed to remove trials with saccades outside the determined fixation area (2°). ANOVAs and t-tests were conducted on the remaining trials to assess error rates and RTs for correct trials.

2.4.1. Squares

Attentional Capture Effect

A paired-samples t-test was conducted to examine the impact of distractor presence on task performance. The results showed that the presence of a salient distractor significantly impaired performance. Specifically, participants made more errors in distractor-present trials (*Figure 7A*), *t* (26) = 3.6, p < .001, Cohen's d = .7 and responded more slowly *t* (26) = -4.7, p < .001, Cohen's d

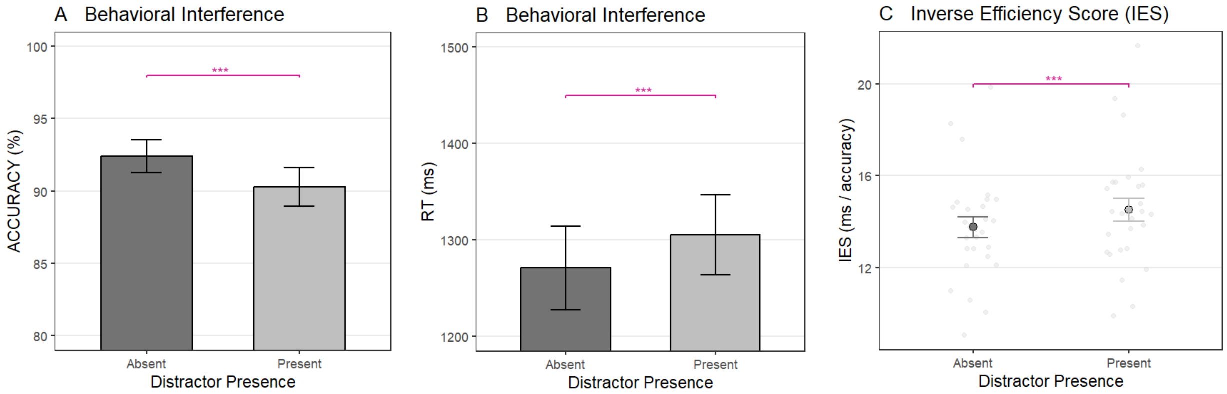


Figure 7. Attentional capture effect for different performance measures. A) Accuracy, B) Reaction Times, and C) Inverse Efficiency Score for distractor-absent and distractor-present trials. The figure illustrates how the presence of a distractor affected performance, with lower accuracy, slower responses, or higher inverse efficiency indicating attentional capture by the salient distractor. Significance levels are indicated as p < .05 (*), p < .01 (**), and p < .001 (***).

= -.9 (*Figure 7B*). These results confirm the classic attentional capture effect, indicating that irrelevant but salient stimuli interfere with target processing.

To integrate speed and accuracy, we computed the Inverse Efficiency Score (IES). Participants showed higher IES values in distractor-present trials than in distractor-absent trials (t (26) = -5.4, $p < .001$, Cohen's d = -1.03), confirming reduced performance efficiency in the presence of distractors (*Figure 7C*).

Practice Effect

To investigate how the impact of distractors changed over time, we conducted a 2 (Distractor Presence: absent, present) x 6 (Block: 1–6) repeated-measures ANOVA on error rates. Both Distractor Presence, F (1, 26) = 12.4, $p < .01$, $\eta^2_p = .32$, and Block, F (5, 130) = 3.3 $p < .001$, $\eta^2_p = .11$, showed significant main effects, indicating that participants made fewer errors over time (*Figure 8A*), and performed worse in distractor-present trials overall. Importantly, there was a significant interaction between these factors (F (5, 130) = 2.8, $p < .05$, $\eta^2_p = .10$), suggesting that the improvement in accuracy across blocks differed depending on distractor presence.

A corresponding ANOVA on RTs revealed a similar pattern of main effects for Distractor Presence, F (1, 26) = 29.6, $p < .001$, $\eta^2_p = .53$, and Block, F (5, 130) = 37.3, $p < .001$, $\eta^2_p = .59$, with no significant interaction ($p > .05$). As expected, participants became faster across blocks, but this improvement occurred regardless of distractor presence, reflecting a general practice effect over time (*Figure 8B*).

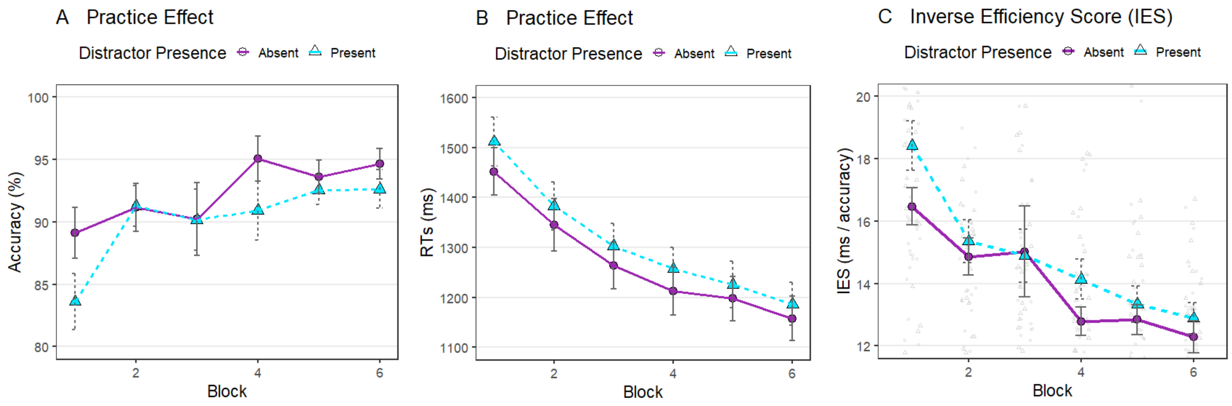


Figure 8. Practice effect for different performance measures. A) Accuracy, B) Reaction Times, and C) Inverse Efficiency Score for distractor-absent and distractor-present trials across Blocks.

When analyzing IES scores across blocks, we observed significant main effects of Distractor Presence F (1, 26) = 14.1, $p < .001$, $\eta^2_p = .35$, and Block, F (5, 130) = 11.6, $p < .001$, $\eta^2_p = .31$, as well as a significant interaction, (F (5, 130) = 11.6, $p < .05$, $\eta^2_p = .09$) (*Figure 8C*).

Although the Distractor Presence by Block interaction did not reach significance for RTs, it emerged for accuracy and IES. Together, these findings suggest that participants gradually learned to better deal with distractor interference over time, reflected in a greater improvement in performance in distractor-present vs. -absent trials.

2.4.2. Pictures

Attentional Capture Effect

A repeated-measures ANOVA was conducted to examine the effect of Distractor Type (absent, negative, neutral) on task performance. The analysis revealed a significant main effect of Distractor Type on both accuracy, F (2, 52) = 21.3, $p < .001$, $\eta^2_p = .45$, and RTs, F (2, 52) = 21.3,

$p < .001$, $\eta^2_p = .45$, indicating that distractor presence had an impact on both the accuracy and the speed of the response.

Post-hoc comparisons showed that participants made fewer errors in distractor-absent trials compared to both negative distractor (*t* (26) = 5.15, p < .001, Cohen's d = .99), and neutral distractor trials (*t* (26) = 3.8, p < .001, Cohen's d = .7). Moreover, error rates were higher for negative than neutral distractors (*t* (26) = -4.65, p < .001, Cohen's d = -.9), suggesting that negative distractors were particularly disruptive (*Figure 9A*).

A similar pattern was found for RTs (*Figure 9B*): participants responded faster in distractor-absent trials than trials with negative (*t* (26) = -5.2, p < .001, Cohen's d = -1.01) or neutral distractors (*t* (26) = -5.6, p < .001, Cohen's d = -1.07). However, RTs did not significantly differ between negative and neutral distractor trials, suggesting that the slowing of responses was primarily driven by distractor salience rather than emotional valence. This differs from the accuracy results, which revealed a valence-specific effect, where negative distractors caused more errors than neutral ones.

To better understand the results in RT and accuracy, we computed the IES. The analysis confirmed a significant main effect of Distractor Type, F (2, 52) = 25.4, $p < .001$, $\eta^2_p = .50$. Pairwise comparisons revealed significant differences between distractor-absent and negative (*t* (26) = –5.2, p < .001, Cohen's d = –0.99), between distractor-absent and neutral (*t* (26) = –5.1, p < .001, Cohen's d = –0.99), and between negative and neutral distractors (*t* (26) = 3.9, p < .001, Cohen's d = 0.75) (*Figure 9C*).

Notably, even though RTs did not differ significantly between negative and neutral distractors, IES values did, suggesting that the emotional valence of the distractor impacted overall performance efficiency beyond mere response slowing. These results answer our first question,

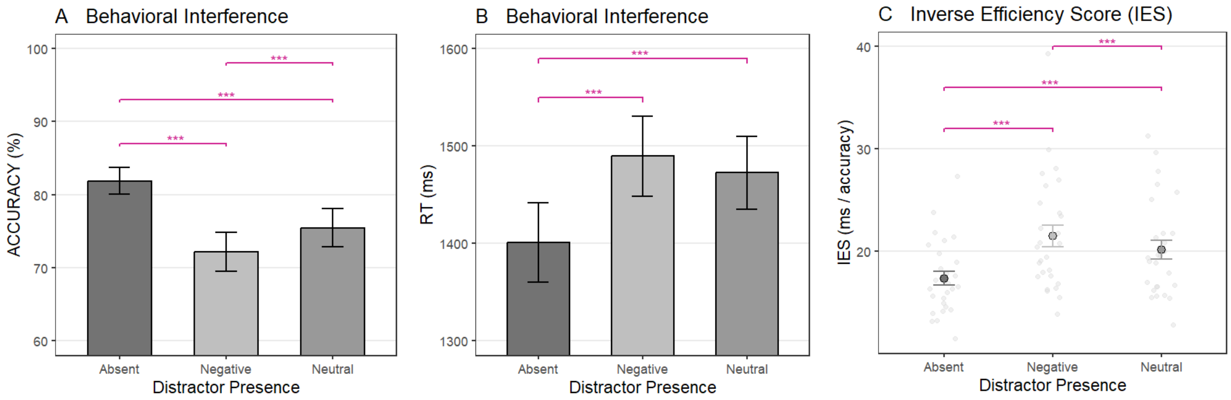


Figure 9. Attentional capture effect for different performance measures. A) Accuracy, B) Reaction Times, and C) Inverse Efficiency Score for distractor-absent and distractor-present trials. Significance levels are indicated as $p < .05$ (*), $p < .01$ (**), and $p < .001$ (***).

indicating that negative emotional stimuli are especially potent in capturing attention involuntarily, interfering with the overall deployment of attentional resources.

Practice Effect

To assess how performance changed over time, a 3 (Distractor Type: absent, present negative, present neutral) x 6 (Block: 1–6) repeated-measures ANOVA was conducted on error rates. There was a significant main effect of Distractor Type, $F(2, 52) = 22.8$, $p < .001$, $\eta^2_p = .47$, indicating that accuracy differed depending on the type of distractor. However, neither the main effect of Block nor the interaction between Distractor Type and Block reached significance ($p > .05$), suggesting that accuracy did not systematically change over time and that learning did not differ across conditions (*Figure 10A*).

A repeated-measures ANOVA on RTs revealed significant main effects of Distractor Type, $F(2, 52) = 19.2$, $p < .001$, $\eta^2_p = .42$, and Block, $F(5, 130) = 16.6$, $p < .001$, $\eta^2_p = .4$, but no significant interaction ($p > .05$). These results indicate that participants generally responded faster over time,

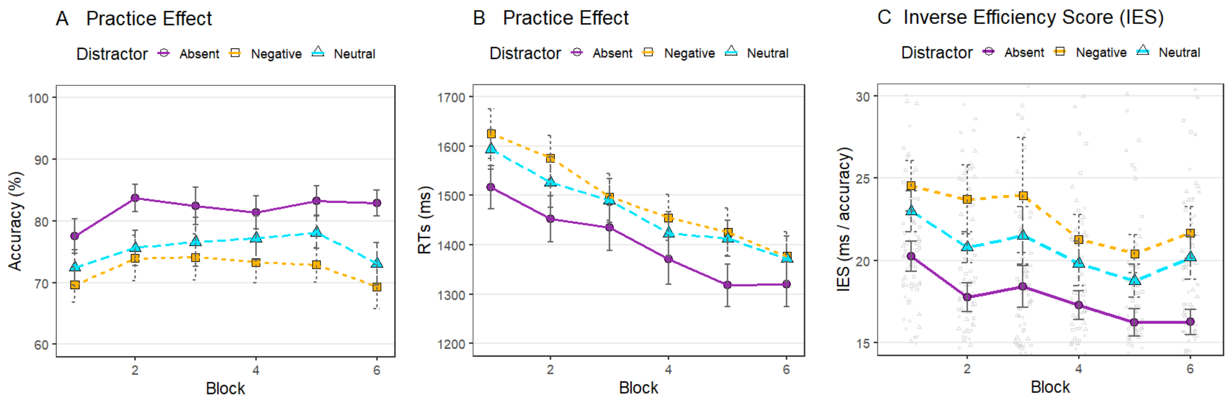


Figure 10. Practice effect for different performance measures. A) Accuracy, B) Reaction Times, and C) Inverse Efficiency Score for distractor-absent and distractor-present trials across Blocks.

reflecting a general practice-related improvement, but that this effect occurred similarly across all distractor conditions, regardless of distractor type (*Figure 10B*).

A further 3 (Distractor Type) x 6 (Block) ANOVA on IES revealed significant main effects of Distractor Type, F (2, 52) = 15.2, $p < .001$, $\eta^2_p = .37$, and Block, F (5, 130) = 3.6, $p < .01$, $\eta^2_p = .12$, with no significant interaction ($p > .05$) (*Figure 10C*). These findings indicate that participants' overall efficiency improved across blocks, consistent with a general practice effect, independent of distractor type.

Taken together, these findings demonstrate that the presence of emotional distractors impairs task performance, with negative distractors exerting a stronger disruptive influence than neutral ones. This interference was particularly evident in accuracy measures, whereas RTs reflected a more general cost of salient distractor, indicating that negative valence intensifies disrupting effects, while showing no comparable modulation on RTs. Despite distractor interference, participants' overall performance improved across blocks, reflecting a gradual practice-related enhancement in efficiency that occurred independently of distractor type.

2.4.3. Stimulus Complexity: Simple Shapes versus Complex Picture Stimuli

To assess the effects of stimulus complexity and emotional valence on attentional performance, repeated-measures ANOVAs were conducted separately on accuracy and RTs, with stimulus complexity (simple vs. complex), distractor presence (absent vs. present), and block as within-subject factors separately for negative and neutral valenced stimuli.

The comparison between simple shape stimuli and both complex negative and complex neutral stimuli revealed a highly consistent pattern of results. Across both analyses, stimulus complexity exerted a robust influence on performance, with participants responding more slowly (simple versus negative: $F(1, 26) = 62.9$, $p < .001$, $\eta^2_p = .71$; neutral: $F(1, 26) = 57.9$, $p < .001$, $\eta^2_p = .69$) and less accurately to complex picture stimuli than to simple shape stimuli (simple versus negative: $F(1, 26) = 73.7$, $p < .001$, $\eta^2_p = .74$; neutral: $F(1, 26) = 66.5$, $p < .001$, $\eta^2_p = .72$). Distractor presence also reliably impaired performance, resulting in reduced accuracy (simple versus negative: $F(1, 26) = 32.6$, $p < .001$, $\eta^2_p = .56$; neutral: $F(1, 26) = 19.1$, $p < .001$, $\eta^2_p = .42$) and longer response times (simple versus negative: $F(1, 26) = 45.2$, $p < .001$, $\eta^2_p = .6$; neutral: $F(1, 26) = 52.75$, $p < .001$, $\eta^2_p = .67$), indicating that irrelevant stimuli successfully captured attention and interfered with task performance. Furthermore, significant effects of block were observed for both accuracy (simple versus negative: $F(5, 130) = 2.4$, $p < .05$, $\eta^2_p = .09$; neutral: $F(5, 130) = 2.5$, $p < .05$, $\eta^2_p = .09$) and RTs (simple versus negative: $F(5, 130) = 29.1$, $p < .001$, $\eta^2_p = .53$; neutral: $F(5, 130) = 28.4$, $p < .001$, $\eta^2_p = .52$), suggesting that performance changed over the course of the experiment, likely reflecting practice-related improvements.

Moreover, the impact of distractor presence on accuracy differed between simple and complex stimuli, although this interaction was substantially stronger for negative stimuli ($F(1, 26) = 19.9$,

$p = .001$, $\eta^2_p = .43$) than for neutral stimuli ($F(1, 26) = 8.01$, $p = .01$, $\eta^2_p = .24$). A similar interaction was observed for RTs only in the negative condition ($F(1, 26) = 5.9$, $p = .05$, $\eta^2_p = .2$), indicating that emotionally negative stimuli amplified distractor-related slowing beyond the effects attributable to stimulus complexity alone. In addition, interactions between stimulus complexity and block on RTs (negative: $F(5, 130) = 4.3$, $p < .01$, $\eta^2_p = .14$; neutral: $F(5, 130) = 6.6$, $p < .001$, $\eta^2_p = .2$) suggest that differences between simple and complex stimuli evolved across the experiment, reflecting changes in attentional processing over time.

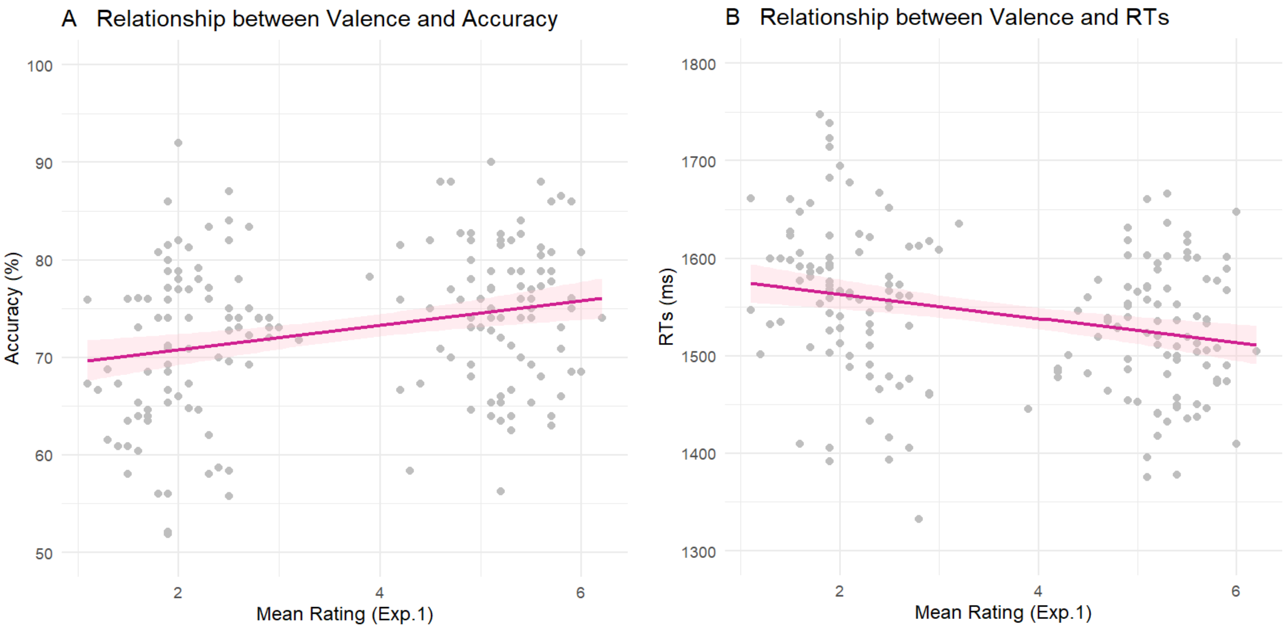
When considered alongside the valence analyses reported in *Section 2.4.2*, these findings indicate that the observed effects cannot be explained solely by differences in visual complexity. Although complexity strongly influenced attentional performance, emotional valence contributed additional variance, particularly in modulating the extent to which distractors captured attention. Taken together, both stimulus complexity and emotional valence play a certain role in the modulation of attentional processing, with complexity affecting overall task difficulty and emotional valence further enhancing the attentional impact of distracting information.

2.4.4. Exploratory Analysis

Interaction Between Valence Ratings and Performance

To further explore the role of emotional valence, we examined whether task performance in Experiment 2 was modulated by the valence of individual pictures. To this end, we performed a linear mixed-effects model to examine whether the mean valence ratings of the pictures obtained from the Standardization Experiment (Experiment 1) predicted participants' accuracy and RTs in Experiment 2.

The results revealed a significant effect of valence on accuracy (Estimate = 1.26, SE = 0.35, *t* (178.74) = 3.63, p < .001), and RTs (Estimate = –11.35, SE = 3.20, *t* (178.01) = –3.55, p < .001), indicating that as the mean valence ratings increased (i.e., pictures were rated as less negative), participants performed better (*Figure 11A*). In particular, pictures with lower valence ratings were associated with reduced accuracy (*t* = 3.6, p < .001) and slower response times (*t* = -3.6, p < .001), highlighting the disruptive impact of the negative valence of distractors on attentional processing (*Figure 11B*). Overall, the model supports the notion that the negative valence of the pictures affects task performance, with more negative stimuli being associated with lower accuracy and slower responses.


A Relationship between Valence and Accuracy

B Relationship between Valence and RTs

Figure 11. Regression analysis between mean valence ratings and behavioral performance in terms of accuracy (A) and RT (B). Each point represents a participant's average, and the regression line indicates the overall trend. The figure shows how performance varied as a function of stimulus valence. A positive slope in accuracy indicates better performance for neutral stimuli, while a negative slope in reaction time indicates slower responses as stimuli become more negative.

The First Saccade

In spite of task instructions, sometimes participants made a saccade upon display onset. Therefore, we set out to analyze the direction of such unwanted saccades. The landing position of the first eye movement was used to assess the attentional processing of each element (Gaspelin & Luck, 2018b). For this reason, we analyzed the percentage of first saccades landing on each display element (target, filler, or distractor) across conditions. It is important to note that the number of elements (target, filler, and distractor) in the display varied depending on the presence or absence of a distractor: when no distractor was present, fillers occupied three positions, whereas in distractor-present trials, fillers occupied two positions. The reported percentages account for this difference and should also be interpreted accordingly.

As shown in Figure 12, in the Square condition, the first saccades most frequently landed on the target location, with the exception of the distractor-present condition. When a distractor appeared on the display, participants not only made more saccades compared to distractor-absent trials, but their first saccades were also more often directed toward the distracting stimulus. This suggests

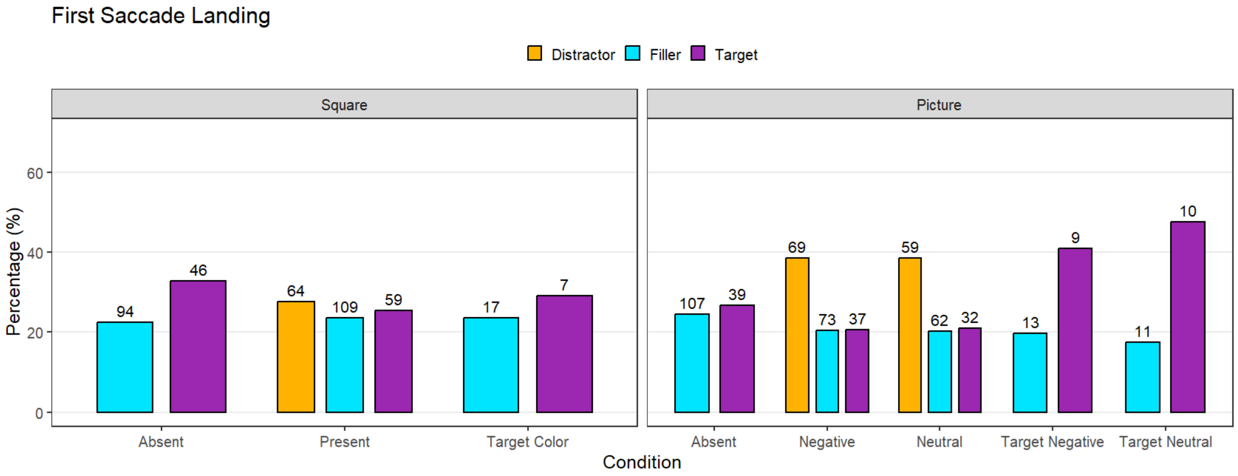


Figure 12. Distribution of first saccade landings across the stimulus displays.

that the presence of a salient element increased competition between target and distractor; as a consequence, disrupted efficient attentional guidance toward the target stimulus. Similarly, in the picture condition, first saccades were mainly guided toward the target stimulus, although a noticeable increase in saccades was observed when a distractor was present, especially when the distractor was a negative picture. However, negative and neutral distractor conditions differed only slightly.

In general terms, these findings, together with the behavioral findings, suggest that salience, in a general sense, competes for attentional selection, leading to increased orienting responses toward irrelevant stimuli.

2.5. Conclusion

The current study investigated the effect of salient and emotionally charged distractors on visual search performance and any modulations of the measured interference over time. Consistently, across both the Square and Picture display conditions, results demonstrated that salient distractors interfered with task performance, although the magnitude of this interference varied with distractor type and emotional valence.

In the square display condition, salient distractors elicited a robust attentional-capture effect. The presence of a salient distracting stimulus resulted in increased error rates and slower responses compared to trials without a distractor. These findings closely align with previous literature, which shows that salient distractors cause strong competition for attentional priority, impairing the efficiency of goal-directed search (Gaspelin et al., 2015, 2017). As expected, participants showed improvement in overall accuracy and response time across blocks, reflecting a general practice effect that unfolded over time, regardless of the presence of distractors. The data indicated that distractor interference was especially pronounced early in the experimental session, whereas extended experience with the task led to a gradual increase in performance efficiency, presumably reflecting the progressive engagement of a learning-dependent mechanism to counteract distraction.

In the picture display condition, the emotional valence additionally modulated the degree of distractor interference. Performance was consistently better in distractor-absent trials than in trials containing either neutral or negative pictures, with negative distractors causing the greatest disruption. This confirms that attentional competition was modulated by the emotional valence, beyond the general cost engendered by a salient, irrelevant stimulus. Importantly, the use of complex real-world pictures proved effective in inducing interference patterns similar to those with simpler geometrical shapes. Differently from the square display condition, accuracy did not change systematically over time, and practice effects in reaction time were uniform across distractor conditions. These results suggest that while emotional distractors exerted a persistent disruptive influence, participants nonetheless exhibited a general decrease in processing time over blocks that did not depend on the emotional valence of the distractor.

Finally, across both square and picture conditions, eye-movement analyses supported the behavioral results, showing that distractor-present trials triggered more saccades and diverted initial saccades toward the task-irrelevant stimulus. Especially in the picture display condition, negative distractor-present trials elicited the highest number of saccades toward the task-irrelevant stimulus.

The results of the regression analysis further strengthened the previous interpretations by revealing a noticeable relationship between subjective evaluation of emotional pictures and task performance

(*Figure 11*). Pictures rated as more negative were associated with lower accuracy and slower responses. The positive slope for accuracy indicated better performance as valence increased, while the negative slope for RTs reflected faster responses to pictures rated as less negative. Collectively, these findings indicate that the greater emotional negativity amplified the distractor's capacity to capture attention and impair performance. This alignment between subjective valence ratings and behavioral results highlights the powerful role of emotional salience in modulating attentional orientation.

Taken together, these findings demonstrate that both simple shape and complex emotionally salient distractors exert a significant impact on attentional control, indicated by slower responses and reduced accuracy. While the effects observed with simple shape stimuli replicate the previous results in the literature (Ferrante et al., 2018), the inclusion of complex pictures revealed that emotionally charged distractors can produce comparable, and even amplified, interference. Although participants showed a general improvement in processing efficiency over time, this learning did not remarkably diminish the disruptive influence of emotional distractors. Overall, the results demonstrate the persistent and particularly potent impact of negative emotional stimuli on attentional guidance and oculomotor behavior, highlighting the integral role of emotional salience in shaping visual attention.

3. EXPERIMENT 3:

CAN STATISTICAL LEARNING BE USED TO CONTROL DISTRACTION FROM EMOTIONAL STIMULUS?

The design and experiment materials (i.e., pictures and squares) of the third experiment were the same as the second experiment. In this experiment, we introduced a highly probable distractor location. The aim was to demonstrate the reduced capture by the salient distractors when they appear in a high-probability location relative to other locations, as previously shown, and test whether such reduce capture would occur also with emotionally charged distractors. We expect that the interference caused by a distractor should be reduced if the distractor happens to be presented at the high probability location, regardless of the distractor type. To this end, we manipulated the appearance probability of distractors, presenting them in different spatial locations, with high (60%) or low (13.33%) probabilities. We aimed to answer whether suppression induced by a statistical learning paradigm would be capable of contrasting the particularly strong interference caused by emotionally negative distractors.

3.1. Participants

An a priori power analysis (G*Power 3.1; Faul et al., 2009) was conducted for a within-subjects 2 (Emotion: negative vs. neutral) x 2 (Distractor: absent vs. present) x 2 (Probability: high vs. low) design. Although Experiment 2 revealed a very large main effect of emotional content ($\eta^2_p = .45$), indicating that a small sample would be sufficient to detect this effect, the critical question in the present study concerns the Emotion x Statistical Learning interaction. Therefore, we powered the study to detect a medium-sized interaction effect. We aimed to test a minimum of 35 participants, which provides good sensitivity to medium effects while remaining feasible in terms of data collection.

A total of 38 (29 females; mean age ± SD, 22.5 ± 3.8) participants took part in this experiment; however, four participants were excluded from the final sample due to accuracy below 70%. All remaining participants (26 females; mean age ± SD, 22.6 ± 3.96) had normal or corrected-to-normal vision, and they received fixed monetary compensation (15 euros) and gave written informed consent before participation.

3.2. Design and Procedure

Different from the previous experiment, in this experiment, the probability of distractor occurrence at the four positions was manipulated. In distractor-present trials, distractors appeared 60% of the times in one of the four positions, and the remaining 40% equally subdivided by the other three positions. The high-probability distractor position was randomized across participants. The experiment consisted of 800 trials following a 20-trial practice phase. On half of the trials, the search display contained colored squares (i.e., red or green), whereas on the other half it contained pictures. A distractor was present on 60% of the trials in each display condition. In both distractor-absent and -present trials, the target appeared in each location with equal probability.

The distractor-absent condition consisted of 128 trials for each condition (picture, squares), and distractor-present condition trials were categorized by distractor type (neutral, negative, square color red and green salient distractor), each condition had 120 trials. In addition, there were probe trials with 16 trials for each condition (target unique color red and green, target unique neutral and negative). In this case, the target was the unique stimulus, besides having a different form, among all the other stimuli, and the distractor was not present. The experiment consisted of four blocks.

In order to assess whether participants were aware of the spatial contingency, they were asked to report verbally whether they had noticed something peculiar about the spatial distribution of either target or distractor stimuli, and to guess the locations where distractors were presented most frequently. For the details of the data analysis, see experiment 2 (*Chapter 2.3*).

3.3. Results

Eye-tracking data were analyzed to remove trials with saccades outside the determined fixation area (2°). ANOVAs and t-tests were conducted on the remaining trials to assess error rates and RTs for correct trials.

3.3.1. Squares

Attentional Capture Effect

A paired-samples t-test was conducted to compare task performance between distractor-present and distractor-absent trials. The presence of a distractor significantly impaired performance, leading to higher error rates (t (33) = 2.9, p < .01, Cohen's d = .5), and slower RTs (t (33) = -5.7, p < .001, Cohen's d = -.99). These results confirm a robust attentional capture effect, whereby salient distractors interfere with goal-directed visual search (*Figure 13A and 13B*).

The IES analysis further supported these findings (*Figure 13C*). IES values were significantly higher in distractor-present than distractor-absent trials (t (33) = –5.6, p < .001, Cohen's d = –0.95), indicating reduced overall performance efficiency in the presence of salient distractors.

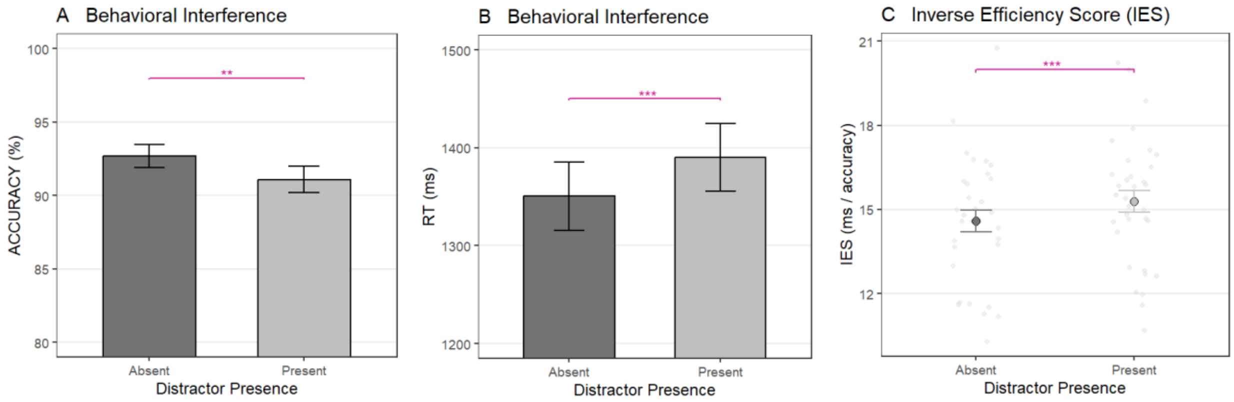


Figure 13. Attentional capture effect for different performance measures. A) Accuracy, B) Reaction Times, and C) Inverse Efficiency Score for distractor-absent and distractor-present trials. Significance levels are indicated as $p < .05$ (*), $p < .01$ (**), and $p < .001$ (***).

Practice Effect

To investigate how performance varied over time, a 2 (Distractor Presence: absent, present) x 4 (Block: 1–4) repeated-measures ANOVA was conducted on error rates. Significant main effects were found for Distractor Presence, $F(1, 33) = 7.7$, $p < .01$, $\eta^2_p = .19$, and Block, $F(3, 99) = 25.7$, $p < .001$, $\eta^2_p = .44$, as well as a significant Distractor Presence by Block interaction ($F(3, 99) = 2.8$, $p < .05$, $\eta^2_p = .08$). This interaction indicates that the degree of distractor interference changed over time, specifically, that the distractor related cost decreased across blocks, suggesting that participants progressively learned to counteract distractor interference (*Figure 14A*).

A corresponding ANOVA on RTs revealed a similar pattern of main effects for Distractor Presence, $F(1, 33) = 44.9$, $p < .001$, $\eta^2_p = .58$, and Block, $F(3, 99) = 58.7$, $p < .001$, $\eta^2_p = .64$, while their interaction remained non-significant ($p > .05$). These findings indicate that participants' response time improved across blocks regardless of distractor presence, reflecting a general practice effect over time (*Figure 14B*).

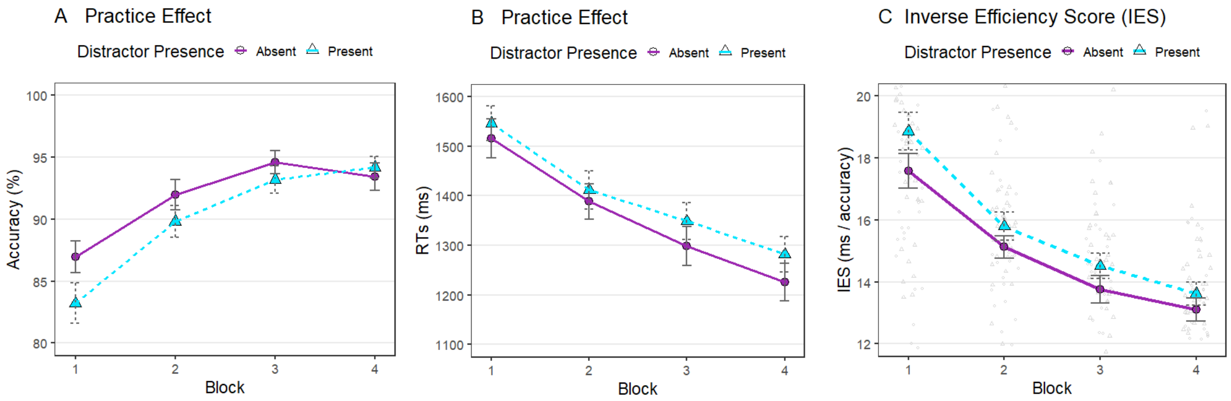


Figure 14. Practice effect for different performance measures. A) Accuracy, B) Reaction Times, and C) Inverse Efficiency Score for distractor-absent and distractor-present trials across Blocks.

The ANOVA on IES revealed significant main effects of Distractor Presence, F (1, 33) = 26.7, p < .001, η^2_p = .45, and Block, F (3, 99) = 61.7, p < .001, η^2_p = .65, with no interaction (p > .05). This confirms that performance efficiency improved across blocks, reflecting accumulated practice with the task, irrespective of distractor presence (*Figure 14C*).

Statistical Learning Effect

A paired-samples t-test was then conducted to examine the effect of Distractor Probability (low, high) on performance. A significant main effect of Distractor Probability emerged for RTs (*t* (34) = –4.24, p < .001, Cohen's d = –0.7), showing that participants responded faster when distractors appeared in the high-probability location compared to low-probability locations (*Figure 15B*). Accuracy did not differ significantly between probability conditions. A direct comparison of IES across Distractor Probability conditions confirmed a robust learning effect (*t* (34) = –3.4, p < .01, Cohen's d = –0.6), showing better performance when the distractor appeared in the high-probability location (*Figure 15C*).

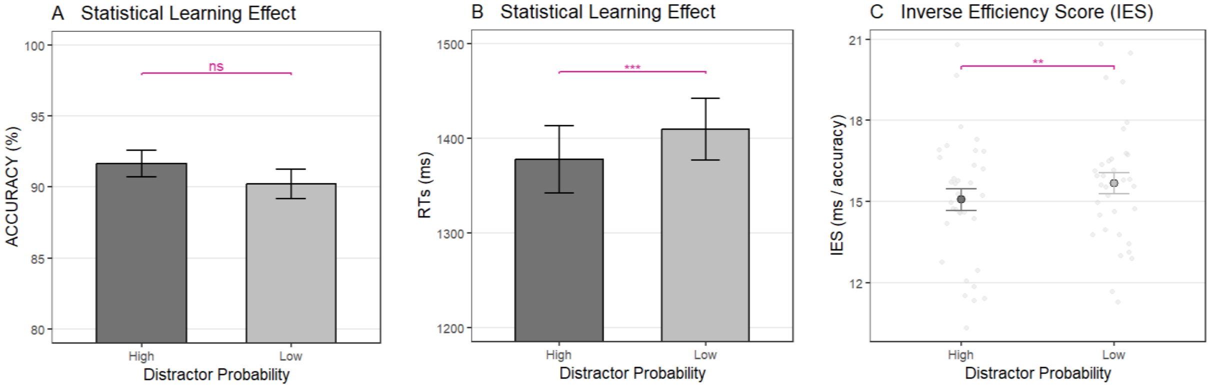


Figure 15. Statistical Learning effect for different performance measures. A) Accuracy, B) Reaction Times, and C) Inverse Efficiency Score for high-probability and low-probability distractor locations. Significance levels are indicated as $p < .05$ (*), $p < .01$ (**), and $p < .001$ (***).

Intertrial Priming Effect

Behavioral results indicated that participants were sensitive to the spatial regularities of the distractors, as evidenced by faster responses when a distractor appeared at the high-probability distractor location compared to all other locations (*Figure 15*). However, manipulating the frequency of distractor occurrence across locations inevitably alters the likelihood that a distractor will appear in the same position across consecutive trials. In other words, the distractor will be presented more often in the high-probability position across consecutive trials. This raises the concern that an intertrial priming effect, which facilitates responses in trials where a distractor appears at the same location as in the previous trial (Kristjánsson & Campana, 2010), will occur disproportionally more often at the high-probability position. Since visual search performance is known to be influenced by such priming effects in a similar way as statistical learning (Maljkovic & Nakayama, 1994; Theeuwes & Van der Burg, 2011), it becomes essential to determine whether the observed effects genuinely reflect learning of spatial regularities rather than short-term repetition benefits.

To determine whether this was the case and to control for the short-term intertrial priming effect, we repeated the main analysis after excluding all trials in which the preceding trial contained a distractor at the same location. Importantly, the observed speeding up of RTs at the high-probability location remained highly reliable even after excluding these trials (*t* (33) = -3.7, p < .001, Cohen's d = -0.64; about 18% of overall trials excluded). These findings are aligned with previous work, which has demonstrated that the beneficial effects of statistical learning for the distractor location can be dissociated from the effects of intertrial priming (Ferrante et al., 2018).

Practice Effect and Statistical Regularities

To further assess how distractor-probability learning unfolded over time, a 2 (Distractor Probability: low, high) x 4 (Block: 1–4) repeated-measures ANOVA was conducted. For accuracy, there was a significant main effect of Block, F (3, 99) = 23.9, p < .001, η^2_p = .42, showing that performance improved across blocks with no further improvement between the third and fourth blocks (*Figure 16A*).

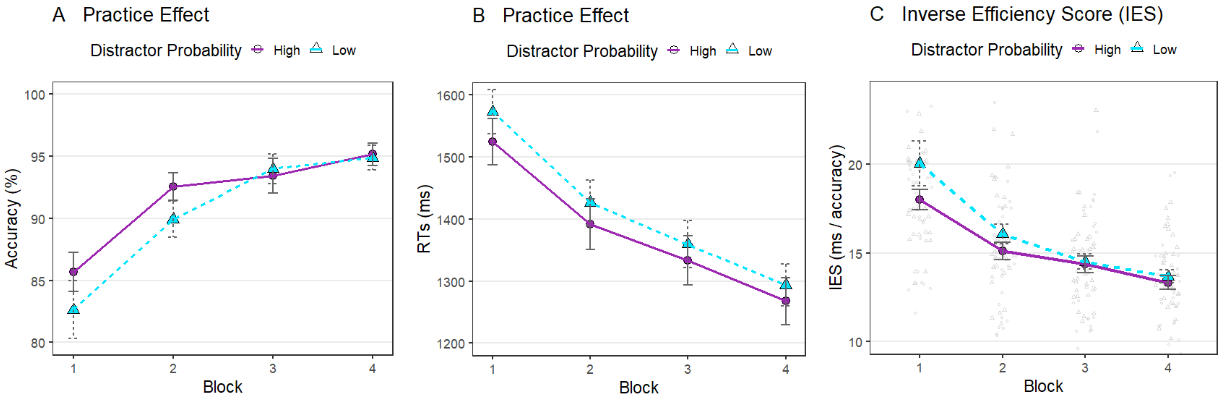


Figure 16. Practice effect and statistical regularities for different performance measures. A) Accuracy, B) Reaction Times, and C) Inverse Efficiency Score for high-probability and low-probability distractor locations across Blocks.

For RTs, both Distractor Probability, F (1, 33) = 19.2, $p < .001$, $\eta^2_p = .37$, and Block, F (3, 99) = 50.7, $p < .001$, $\eta^2_p = .61$, were significant, while their interaction was not ($p > .05$). This pattern suggests that RTs improvements occurred across both high- and low- probability conditions, reflecting a general practice effect, though participants were consistently faster in the high-probability condition.

Finally, a 2 (Distractor Probability: high, low) x 4 (Block) ANOVA on IES revealed significant main effects of Distractor Probability, F (1, 33) = 7.4, $p < .05$, $\eta^2_p = .18$, and Block, F(3, 99) = 31.6, $p < .001$, $\eta^2_p = .50$, whereas no interaction was observed between them ($p > .05$).

3.3.2. Pictures

Attentional Capture Effect

A repeated-measures ANOVA was conducted to examine the effect of Distractor Presence (absent, negative, neutral) on task performance. The analysis revealed a significant main effect of Distractor Presence on both accuracy, F (2, 66) = 31.9, $p < .001$, $\eta^2_p = .5$, and RTs, F (2, 66) = 34.8, $p < .001$, $\eta^2_p = .51$. Participants made fewer errors in the distractor-absent trials compared to both the negative (*t* (34) = 6.6, $p < .001$, Cohen's d = 1.4) and neutral (*t* (34) = 7.04, $p < .001$, Cohen's d = 1.2) distractor-present trials. Similarly, participants responded faster to the target stimuli when no distractor was present compared to when either a negative (*t* (34) = -6.9, $p < .001$, Cohen's d = -1.2) or a neutral (*t* (34) = -5.96, $p < .001$, Cohen's d = -1.02) distractor was present.

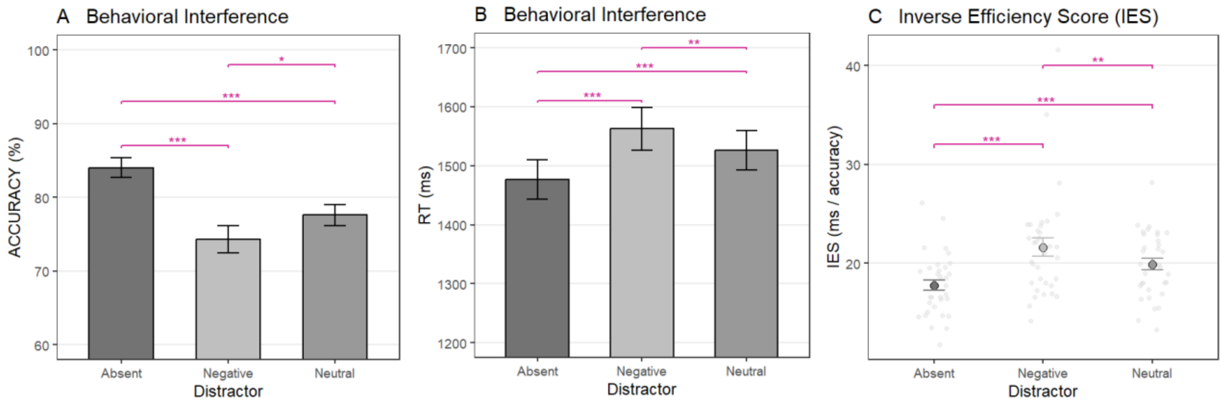


Figure 17. Attentional capture for different performance measures. A) Accuracy, B) Reaction Times, and C) Inverse Efficiency Score for distractor-present and distractor-absent trials. Significance levels are indicated as $p < .05$ (*), $p < .01$ (**), and $p < .001$ (***).

Importantly, performance also differed between the distractor valence types. Participants were less accurate (*t* (34) = -2.6, $p < .05$, Cohen's d = -.45) and slower (*t* (34) = 3.6, $p < .01$, Cohen's d = .6) when the distractor was negative rather than neutral (*Figure 17A and 17B*).

The IES, integrating both accuracy and RTs, revealed a robust effect of Distractor Presence, F (2, 66) = 28.5, $p < .001$, $\eta^2_p = .46$. Pairwise comparisons confirmed significant differences between absent and negative (*t* (34) = -6.1, $p < .001$, Cohen's d = -1.03), absent and neutral (*t* (34) = -8.2, $p < .001$, Cohen's d = -1.4), as well as negative and neutral (*t* (34) = -3.1, $p < .01$, Cohen's d = .5) distractors (*Figure 17C*). These results demonstrate that negative distractors significantly reduced performance efficiency relative to neutral and distractor-absent conditions.

Practice Effect

To examine how distractor interference evolved over time, a repeated-measures ANOVA with Distractor Presence (absent, negative, neutral) and Block (1–4) as within-subject factors was conducted. For accuracy, significant main effects emerged for both Distractor Presence, F (2, 66)

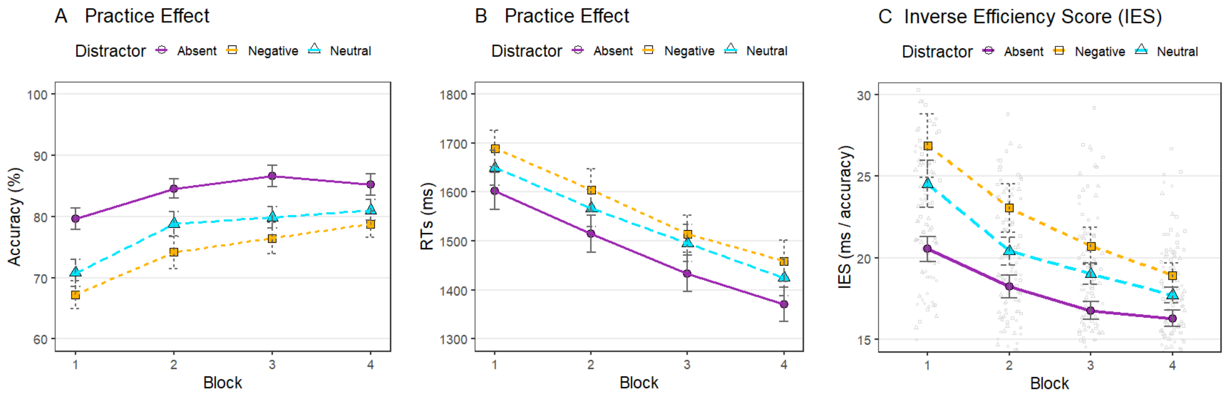


Figure 18. Practice effect for different performance measures. A) Accuracy, B) Reaction Time, and C) Inverse Efficiency Score for distractor-present and distractor-absent trials across Blocks.

= 32.5, $p < .001$, $\eta^2_p = .50$, and Block, F (3, 99) = 12.5, $p < .001$, $\eta^2_p = .28$. Participants made more errors when distractors were present, particularly when they were negative, and overall accuracy improved across blocks, reflecting a general practice effect. For RTs, significant main effects of Distractor Presence, F (2, 66) = 37.4, $p < .001$, $\eta^2_p = .53$, and Block, F (3, 99) = 39.3, $p < .001$, $\eta^2_p = .54$, were observed, indicating that participants responded faster over time irrespective of distractor type (*Figure 18A and 18B*).

A subsequent ANOVA on IES showed significant main effects of Distractor Presence, F (2, 66) = 23.4, $p < .001$, $\eta^2_p = .40$, and Block, F (3, 99) = 19.5, $p < .001$, $\eta^2_p = .37$, as well as a weak but significant interaction, F (6, 198) = 2.65, $p < .05$, $\eta^2_p = .07$. While performance efficiency improved across blocks, the impact of distractors, especially negative ones, remained evident (*Figure18C*).

Together, these results suggest that participants progressively improved their ability to perform the task, although the presence of emotionally salient distractors continued to impair more their performance.

Statistical Learning Effect

To assess the influence of spatial regularities, a repeated-measures ANOVA was conducted on only distractor-present trials with Distractor Probability (low, high) and Distractor Type (negative, neutral) as within-subject factors. Only significant main effects of Distractor Type emerged for both accuracy, F (1, 33) = 6.6, $p < .05$, $\eta^2_p = .17$, and RTs, F (1, 33) = 12.8, $p < .01$, $\eta^2_p = .28$, indicating that negative distractors disrupted performance more than neutral ones (*Figure 19A and 19B*). Although the difference between high and low distractor-probability conditions did not reach significance, RTs showed a near-significant trend ($p = .05$), suggesting that increased spatial predictability facilitated attentional suppression. The IES analysis further confirmed the absence of a significant effect of distractor probability on performance (*Figure 19C*).

To determine whether the efficiency of selecting the target was affected, the RTs and error rates were analyzed. If participants had learned to suppress the high-probability distractor location, target processing at that location should be impaired due to inhibition of that location.

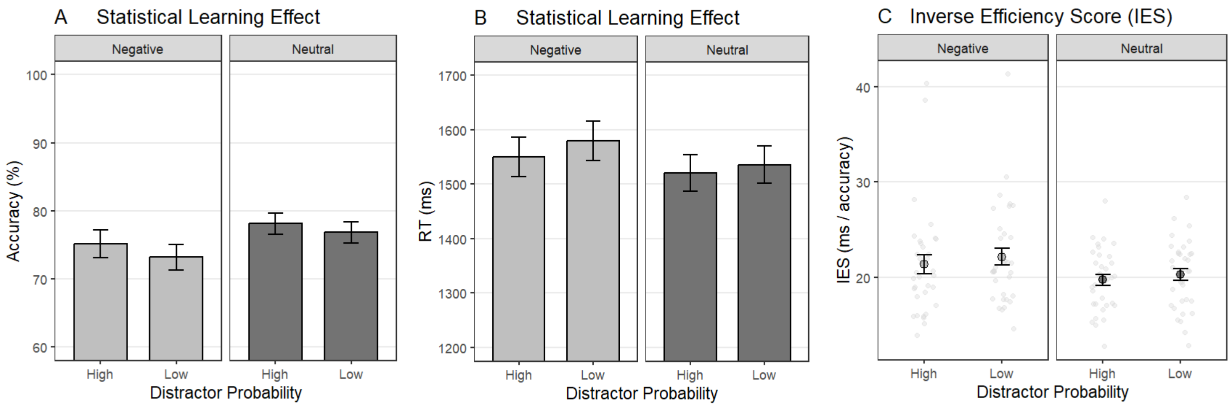


Figure 19. Statistical Learning effect for different performance measures. A) Accuracy, B) Reaction Times, and C) Inverse Efficiency Score for high-probability and low-probability distractor locations.

A repeated-measures ANOVA with Target Position (high vs. low distractor position) x Distractor Presence (absent, negative, neutral) revealed significant main effects of Distractor Presence, F (2, 66) = 19.97, p < .001, η^2_p = .38, and Target Position, F (1, 33) = 6.2, p < .05, η^2_p = .16, on RTs. As shown in Figure 20, participants were slower to respond when the target was presented in the high-probability distractor location compared to other locations (*t* (101) = 2.3, p < .05), which is consistent with the presence of location-based suppression. Although accuracy did not significantly differ, IES analyses confirmed significant effects of Distractor Presence, F(2, 66) = 28.1, p < .001, η^2_p = .46, and Target Position, F (1, 33) = 4.8, p < .05, η^2_p = .13, again indicating that targets appearing in suppressed locations elicited less efficient responses (*t* (101) = 2.34, p < .05).

These findings are in line with selective changes in attentional priority as a function of the introduced statistical regularities; trials in which a target was presented in the high probability distractor location let to slower response times, indicating that target selection was impaired when the target appeared in a high-probability distractor location.

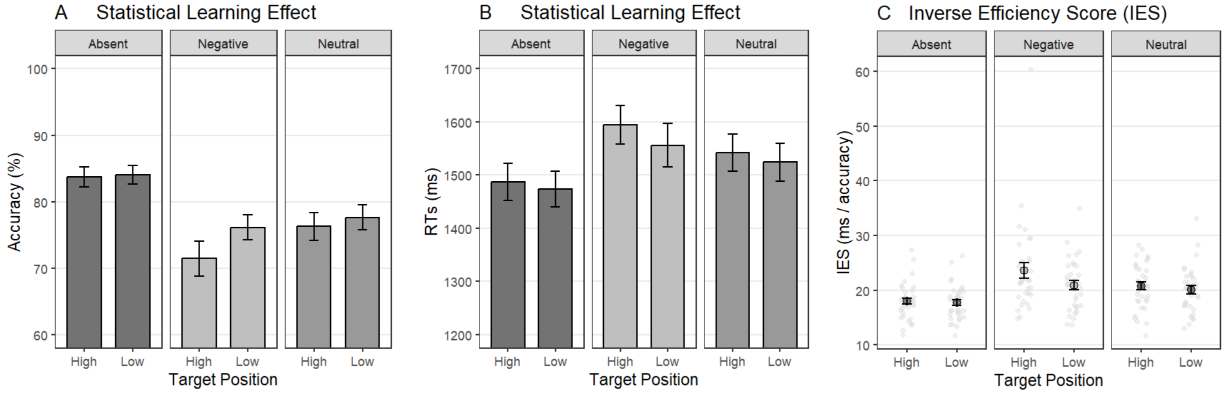


Figure 20. Statistical Learning effect for different performance measures. A) Accuracy, B) Reaction Times, and C) Inverse Efficiency Score for target presented at high- and low-probability distractor locations.

Practice Effect and Statistical Regularities

A further 2 Distractor Probability (high, low) x 2 Distractor Type (negative, neutral) x 4 Block (1–4) ANOVA revealed significant main effects of Distractor Type, F (1, 33) = 6.01, p < .05, η^2_p = .15, and Block, F (3, 99) = 12.7, p < .001, η^2_p = .28, for accuracy. Participants made more errors in trials containing negative distractors, but accuracy improved across blocks, indicating the progressive effect of practice. For RTs, there were significant main effects of Distractor Type, F (1, 33) = 9.4, p < .01, η^2_p = .22, Block, F (3, 99) = 35.6, p < .001, η^2_p = .52, and Distractor Probability, F (1, 33) = 4.5, p < .05, η^2_p = .12. Responses were slower for negative distractors but became faster over time (*Figure 21A*), particularly when distractors appeared at predictable, high-probability locations, reflecting learning of spatial regularities (*Figure 21B*). IES analysis (*Figure 21C*) further confirmed these results, showing a significant effect of Distractor Type, F (1, 33) = 6.4, p < .05, and Block, F (3, 99) = 14.9, p < .001. The trend-level effect of Distractor Probability (p = .07) further suggested that participants partially learned to anticipate and suppress distractors appearing in predictable locations.

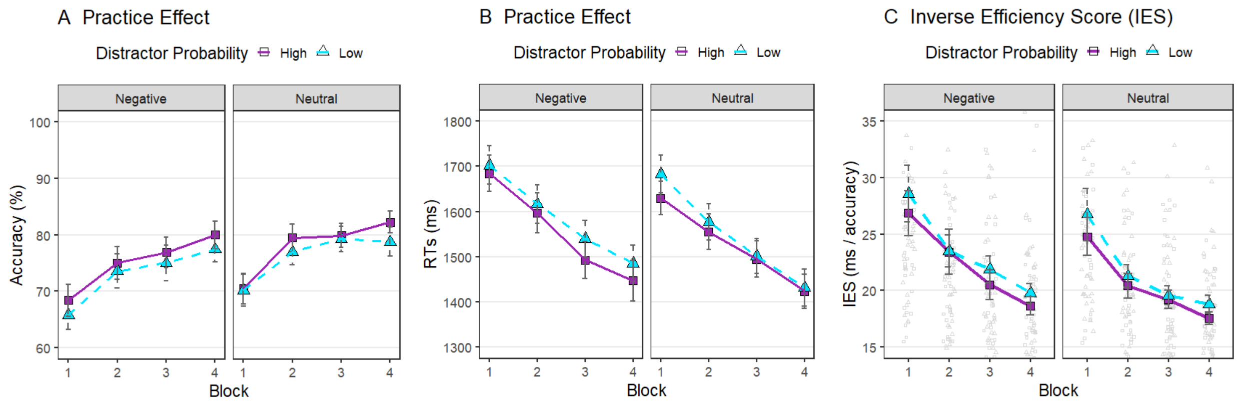


Figure 21. Practice effect and statistical regularities for different performance measures. A) Accuracy, B) Reaction Times, and C) Inverse Efficiency Score for high-probability and low-probability distractor locations across Blocks.

Collectively, our results demonstrate that emotionally negative distractors exerted a stronger disruptive impact on task performance than neutral ones, as reflected by higher error rates, slower reaction times, and reduced efficiency. Nonetheless, the significant main effects of Block across all measures indicate that participants' performance improved with practice. The additional effects of Distractor Probability on RTs and the near-significant trend in IES further suggest that participants learned to anticipate distractor locations, allowing more efficient suppression of interference in predictable contexts. Thus, while negative distractors initially impaired performance, repeated exposure and the acquisition of spatial regularities enhanced attentional control and reduced distractor interference over time.

Overall, the findings replicate the core attentional capture and learning effects observed in Experiment 2. Participants showed clear distractor interference, which diminished over time as they learned to suppress irrelevant stimuli. Furthermore, statistical learning modulated performance: participants responded faster and more efficiently when distractors appeared in predictable, high-probability locations.

3.3.3. Exploratory Analysis

Interaction Between Valence Ratings and Performance

We performed a linear mixed-effects model to examine whether the mean valence ratings of the pictures obtained from the Standardization Experiment (Experiment 1) also predicted participants' accuracy and RTs in Experiment 3.

The results revealed a significant effect of valence on accuracy (Estimate = .975, SE = 0.3, *t* (176.96) = 3.12, p < .01), and RTs (Estimate = -14.3, SE = 3.1, *t* (176.5) = –4.65, p < .001), indicating that as the mean valence ratings increased, participants produced more accurate and faster responses (*Figure 22A and 22B*).

These findings suggest that emotional negativity not only reduces accuracy but also slows down response times, supporting the view that negative affective content captures attention and interferes with goal-directed performance.

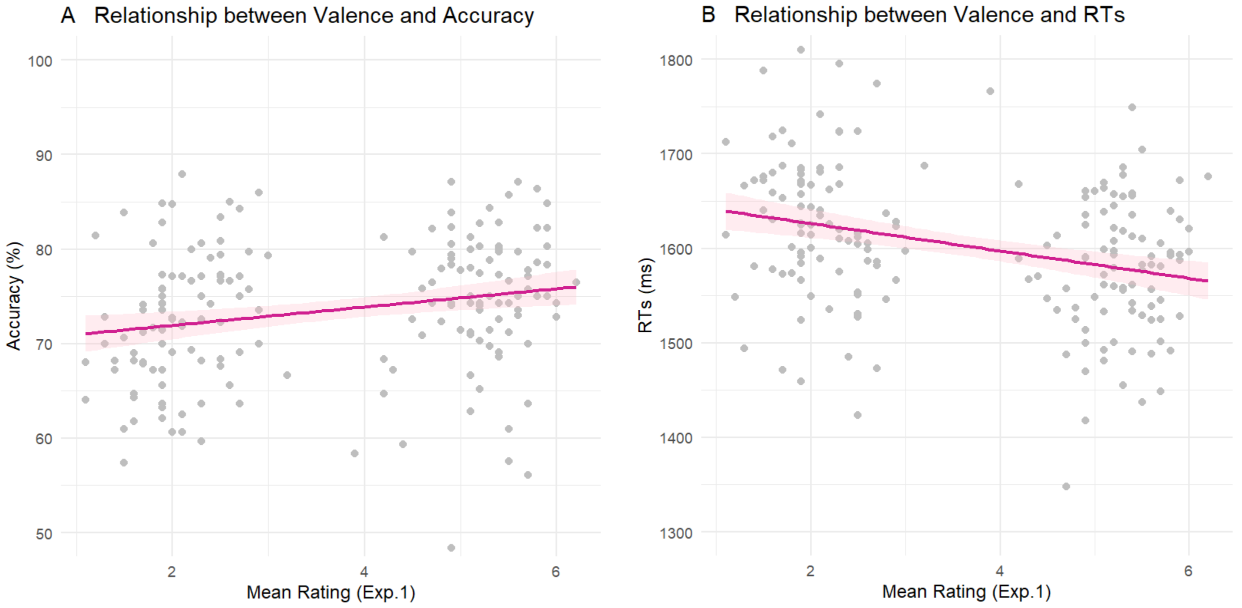


Figure 22: Regression analysis between mean valence ratings and behavioral performance in terms of accuracy (A) and RTs (B). Each point represents a participant's average, and the regression line indicates the overall trend. The figure shows how performance varied as a function of stimulus valence. A positive slope in accuracy indicates better performance for neutral stimuli, while a negative slope in reaction time indicates slower responses as stimuli become more negative.

The First Saccade

We analyzed the percentage of first saccades landing on each display element (target, filler, or distractor) across display type (squares and pictures), and distractor probability (high and low) for Experiment 3 (*Figure 23*). We expected that if the high-probability distractor location is suppressed, then the eyes would be less likely to be directed there, resulting in fewer eye movements toward that position compared to others.

Similar to the previous experiment, also in Experiment 3, participants made more saccades in distractor-present trials compared to distractor-absent trials. In the square display condition, participants consistently made more saccades toward the target, with this effect being particularly pronounced in trials without distractors. Importantly, the presence of a distractor influenced saccadic behavior depending on its location. The distractor captured attention more than the target stimulus only when it appeared in a non-suppressed location.

Similarly, in the picture display condition, participants made more saccades toward the target in distractor-absent trials, and this tendency was particularly strong for targets defined by the unique emotional valence. Interestingly, the position of distractors influenced saccades, along with emotional valence, in picture displays. When the distractor appeared in a low-probability location (non-suppressed), participants tended to make more saccades toward the distractor, with a stronger bias toward negative distractors (> 50%) compared to neutral ones (< 40%), compared to when

Figure 23. Distribution of first saccade landings across the stimulus display

distractors were presented in a high-probability location. In addition, participants made more saccades overall when a negative distractor appeared on the display (negative: 52 vs. neutral: 37).

These findings suggest that saccadic behavior is modulated by display type, distractor probability, and distractor valence, providing further support for the behavioral results.

3.4. Conclusion

The present study investigated how physically, and emotionally salient distractors shape attentional capture, how distractor interference changes with practice, and whether statistical regularities can be leveraged to enhance attentional control. Across both square and picture display conditions, the findings consistently showed that distractors interfered with target selection, with the magnitude of this interference modulated by the complexity of the distractors, their emotional valence, and spatial predictability.

The main results are closely aligned with what observed in Experiment 2. Across both display conditions, we again replicated the core finding that distractor-present trials elicited higher error rates and slower response times compared to distractor-absent trials. Consistent with prior results of Experiment 2, performance was significantly impaired when the distractor had negative emotional valence. The persistent and robust interference associated with negative distractors supports the idea that emotional salience increases the competition for attentional resources. Moreover, unlike in the square display condition, practice effects in the case of picture stimuli were more limited. Although participants became faster over time, emotionally salient distractors continued to disrupt performance. This indicates that the detrimental impact of emotional distractors persists even with extended task experience, suggesting that their influence is more difficult to suppress than the physically salient stimuli.

The effects of statistical learning differed between square and picture display conditions. In the square display condition, participants showed sensitivity to statistical regularities, responding faster and more accurately when distractors appeared in high-probability location. These results replicate the well-established attentional capture reduction by color singletons reported in the literature (Failing & Theeuwes, 2020; Ferrante, Chelazzi, & Santandrea, 2023) and demonstrate that physically salient distractors produce robust interference at first, yet their interference is easier to control when they are predictable. In contrast, the statistical learning effect in the picture condition was more subtle. Although performance did not differ significantly between high- and low-probability distractor locations, the near-significant trend ($p = .5$) suggested emerging spatial predictability effects also for this kind of salient stimulus. This interpretation was further supported by analyses on target location. When the target appeared in the high-probability distractor location, participants responded more slowly, consistent with location-based suppression. This slowdown indicates that participants learned to inhibit the high-probability distractor location over time, regardless of the display type.

One might argue that the observed proactive suppression could reflect inter-trial priming effect, driven by recent trial history rather than experience-dependent learning. Our results demonstrate this was not the case, since attentional modulation persisted beyond short-term trial-to-trial effects, indicating that suppression reflected robust statistical learning rather than short-term influences.

Eye-movement analyses further confirmed strong attentional capture by salient distractors, with participants making more saccades and directing their first saccades more often to the distractor when it was present. Especially, when distractors appeared in non-suppressed (low probability) locations, first saccades were more frequently directed toward them, particularly when the distractor was negative. As expected, distractors presented in the high-probability location captured the eyes less often, demonstrating that learned suppression effectively reduced overt attentional capture, irrespective of display type.

Consistent with behavioral results, valence ratings revealed that picture distractors with more negative evaluations were associated with lower accuracy and slower responses, highlighting the link between subjective emotional evaluations and attentional control.

Overall, the results across both Experiments 2 and 3 give rise to several key conclusions. First, salient distractors, whether simple geometric shapes or complex emotional pictures, robustly capture attention and impair performance. Second, practice reduces distractor interference over time, though emotional distractors seem more resistant to control. Third, statistical learning of distractor regularities enhances attentional suppression, facilitating more efficient target processing when spatial patterns are predictable.

Chapter 5: GENERAL DISCUSSION

DISCUSSION

Attention is a fundamental cognitive process that allows us to select and focus on relevant information in our environment while filtering out irrelevant stimuli. Despite this selective capacity, attention can also be involuntarily captured by salient features, such as color, shape, or emotional valence, even when they are not relevant to the task. Certain stimuli, due to their high attentional priority, are often difficult to suppress (Chelazzi et al., 2019). A growing body of research has shown that the disruptive effects of physically salient distractors can be controlled through experience, particularly when distractors appear with predictable regularities in visual space. In such cases, statistical learning allows observers to proactively suppress likely distractor locations, thereby improving performance (Ferrante et al., 2018; Wang & Theeuwes, 2020). Yet, the generalizability of such mechanisms to complex, emotionally salient stimuli has remained largely unexplored. Traditional studies often rely on simple stimuli, such as geometric shapes, words, or pure tones, to induce attentional capture effect (Liesefeld et al., 2024). While they can be highly informative, in real-word context selective attention is primarily guided by motivational significance (Lang, Bradley, & Cuthbert, 1997). Crucially, the sources of salience (emotional versus physical) do not appear to rely on the same mechanisms. Stimuli with motivational value, particularly negative ones, are more likely to capture and sustain attention than neutral, repeated events, triggering automatic responses that often cause greater interference in ongoing tasks (Campbell, Wood, & McBride, 1997; Grimshaw et al., 2018; Ferrari, Canturi, & Codispoti, 2022). Even if the initial sensory trigger operates in an all-or-nothing fashion analogous to bottom-up processing, the intensity and nature of the subsequent response are subject to top-down modulation (Xue & Pourtois, 2025). Therefore, the present work aimed to address this gap by investigating how emotional distractors influence attentional allocation, how their interference evolves with task practice, and whether statistical learning can facilitate proactive suppression to reduce their distracting power. Understanding these mechanisms is essential for comprehending how task-irrelevant information is processed and how performance can be optimized in daily life.

Accordingly, our first aim was to examine how distractor presence modulates performance. Replicating previous work, we found that both physically and emotionally salient distractors impaired target detection, reducing accuracy and increasing reaction times in distractor-present trials (Gaspelin et al., 2015, 2017; Haro et al., 2020; Ferrari, Canturi, & Codispoti, 2022). These results support the notion that salient stimuli compete for limited attentional resources and can involuntarily capture attention away from task-relevant targets. However, the degree and persistence of this interference differed between display and distractor types. Even though simple geometric physically salient distractors elicited robust attentional capture initially, performance improved gradually with practice, reflecting general learning and improved efficiency. This pattern aligns with evidence indicating that attentional capture by physically salient distractors can be attenuated through experience and repeated exposure. In contrast, emotionally salient picture distractors, particularly those with negative valence, exerted a persistent disruptive effect that was less compliant to attenuation through repeated exposure. Although some improvement was observed with practice, these distractors continued to impair performance to a greater extent than physically salient distractors, as reflected by lower accuracy and longer reaction times. This persistence suggests that emotional stimuli possess a privileged status in attentional processing, making them more resistant to suppression. From an evolutionary perspective, stimuli conveying potential threat or danger may continue to attract processing resources even when they are irrelevant to current goals, thereby ensuring rapid detection of information with potential survival value (Lang, Bradley, & Cuthbert, 1997; Vuilleumier et al., 2001; Murphy et al., 2020). At the same time, our findings indicate that emotional valence alone cannot fully account for the observed interference effects. Both negative and neutral picture distractors produced greater disruption than simple geometric shapes, suggesting that stimulus complexity was an important determinant of attentional capture. Complex naturalistic images contain substantially more visual information than simple geometric forms and therefore place greater demands on perceptual processing. Nevertheless, the role of emotion remained evident when comparing negative distractors with neutral ones. Negative distractors consistently produced larger and more persistent interference effects than neutral distractors, despite comparable levels of visual complexity. This finding demonstrates that emotional valence amplifies attentional capture beyond the effects attributable to complexity alone. Together, these results suggest that attentional interference arises from the combined influence of perceptual complexity and emotional significance, with emotionally negative stimuli exerting a particularly strong capture of attention due to their enhanced motivational relevance for survival (Lang, Bradley, & Cuthbert, 1997; Murphy et al., 2020).

Building on these findings, the next key question was whether statistical learning could reduce distraction from emotional stimuli. Statistical learning refers to the ability to extract regularities from the environment and use them to guide attention, such that frequently irrelevant stimuli are more efficiently suppressed (Chun & Jiang, 1998). Under typical spatial learning conditions, a high-probability distractor location becomes proactively suppressed, such that stimuli appearing there compete less effectively for attention than stimuli presented at another location (Kong et al., 2020). Conversely, distractors appearing at low-probability locations tend to capture attention strongly, drawing resources away from target processing (Murphy et al., 2020). This is consistent with the signal suppression hypothesis (Sawaki & Luck, 2010), which posits that while salient distractors inherently generate a strong bottom-up "notice me" signal, attentional capture is not mandatory and can be prevented through proactive inhibition of distractor signals before they trigger attentional shifts.

Consistent with prior research (Wang et al., 2019; Failing & Theeuwes, 2020; Ferrante et al., 2023), clear evidence of statistical learning emerged in the square display condition. Distractors appearing in the high-probability locations produced smaller behavioral costs and reduced oculomotor capture. These findings indicate that participants learned the spatial regularities and proactively adjusted attentional priority, thereby enabling more effective control over attentional capture by distractors. In the picture display condition, instead, the effects of statistical learning were subtler. Although differences between high- and low-probability locations did not reach significance, behavioral trends suggested emerging spatial suppression. To some extent, negative distractors can still be partially suppressed when reliable spatial regularities are present, even though they initially attract attention (Chen et al., 2025). Moreover, the performance costs associated with targets appearing in locations that frequently contained distractors provide further evidence for learned spatial inhibition. The presence of spatial suppression in the square condition and its absence in the picture condition, might be explained better by the differential competition between targets and distractors at high- versus low- probability locations when emotional stimuli are involved. The findings suggest that the statistical learning mechanism is effective for simple geometric distractors but is challenged by emotionally salient distractors. While the high-frequency location was suppressed, the emotional distractors overcame this suppression and continued to compete effectively with the target, likely reflects their intrinsic motivational priority within the attentional system, potentially supported by specialized mechanisms for rapid, preattentive detection of biologically relevant stimuli. Importantly, the presence of target costs at high-probability distractor locations provides additional insight into the mechanism underlying learning-based suppression. Slower and less accurate responses to targets appearing in frequently suppressed locations indicate that inhibition was applied at the level of spatial representations. This finding is consistent with priority-map accounts of attention, according to which locations that repeatedly contain irrelevant information acquire reduced attentional weight over time. As a consequence, both distractors and targets appearing at those locations are processed less efficiently, reflecting a learned bias to deprioritize specific regions of space. In other words, when the target appears at the high-probability location, it loses its competitive advantage due to location-based suppression, whereas emotionally salient distractors appearing at low-probability locations continue to exert strong attentional capture, further impairing target processing.

Importantly, the reduction in distractor interference cannot be attributed to habituation either. De Tommaso and Turatto (2019) demonstrated that when visual search is performed in a singleton-detection mode, as in the present study, capture by a salient distractor does not diminish, even when the distractor color remains constant or when the same distractor is repeatedly presented. By contrast, the results of the current experiment reveal that suppression emerges when the spatial regularities of distractors are predictable. Specifically, we found that different stimuli appearing consistently at a high-probability location led to reliable suppression of that location and more efficient control of salient singleton distractors. This pattern indicates that statistical learning does not reflect mere desensitization to a particular stimulus or dependence on a specific distractor feature, rather, it operates at the level of spatial expectations. Therefore, the observed spatial suppression cannot be attributed to simple habituation to stimulus repetition at that location, rather it reflects the acquisition of predictive knowledge about where irrelevant information is likely to occur.

The reduced efficacy of statistical learning in the picture condition can also be understood in terms of stimulus complexity and novelty. In Experiments 2 and 3, the simple shape (geometric) distractors were defined by a limited set of features (two colors) and were repeated throughout the experiment, facilitating learning and pop-out detection. In contrast, picture distractors contained rich visual and semantic features and were rarely repeated, making each distractor effectively novel. Evidence suggests that emotional pictures, particularly when novel and unpleasant, require greater attentional resources during encoding (Lang, Bradley, & Cuthbert, 1997).

The lack of robust suppression in the picture condition can thus be explained at least in part by stimulus novelty: emotional distractors retained their ability to capture attention because they were rarely repeated. Previous work has demonstrated that effective control of emotional distractors relies on stimulus repetition and familiarity. Vatterott, Mozer and Vecera (2012) showed that distractor filtering is not immediate; rather, successful rejection of salient distractors emerges only after a learning phase involving repeated exposure to the same distractor (De Tommaso & Turatto, 2019). This idea is consistent with Sokolov's (1963) classic account, which posits that the attention orienting is triggered by novel stimuli to evaluate their significance, involving both covert and overt attentional shifts toward potentially important stimuli. Ferrari and colleagues (2011) further demonstrated that repeated exposure to emotionally negative stimuli can reduce their motivational value, allowing them to be treated as "safe" and suppressed. However, when a novel negative picture is presented, this suppression effect disappears, suggesting that the filtering mechanism is primarily tuned to the specific features of repeated stimuli rather than to spatial regularities. One straightforward way to clarify these results would be to increase stimulus repetition, enhancing familiarity and potentially allowing proactive suppression to emerge (Xu et al., 2023). At the same time, novelty alone does not always guarantee attentional orienting, as Ferrari and colleagues

(2022) showed that novel stimuli capture attention only when emotionally salient, whereas novel neutral distractors do not.

Another approach to promote proactive control is to increase the proportion of trials containing distractors, making their occurrence more predictable. Higher distractor frequency reduces attentional capture even from emotionally salient stimuli (Grimshaw et al., 2018), such that neither emotional nor neutral stimuli cause measurable distraction when they appear in 75% of trials (Murphy et al., 2020). Conversely, when distractors appear in only 25% of trials, emotionally salient distractors produce significantly greater response times than neutral ones. Together, these findings indicate that both stimulus repetition and emotional salience interact to shape attentional capture and suppression.

The eye-tracking data provided complementary evidence for these conclusions. More saccades elicited in the distractor-present trials, and initial saccades were more frequently directed toward distractors, particularly those with negative valence, suggesting that emotional stimuli can automatically capture gaze even when participants are instructed to maintain central fixation. In addition, first saccades were less likely to land on high-probability distractor locations, even for negative pictures. This finding provides strong evidence that statistical learning supported some degree of proactive suppression also at the oculomotor level. It is important to note that these eye-movement results come from exploratory analyses, and conclusions regarding oculomotor suppression should therefore be interpreted with caution. A design allowing natural (free) eye movements would provide a more direct and clearer evidence regarding whether emotional distractors are proactively suppressed at the oculomotor level as well (Gaspelin & Luck, 2018b; Ferrante et al., 2018). In such design, observing that first saccades are less frequently directed toward the emotional distractors when they appeared in a high-probability location would indicate that the distractor location was proactively suppressed (Xu et al., 2023). This, in turn, would rule out the possibility that emotional stimuli are first processed and then rejected (Theeuwes, 2010). Instead, it would support the view that suppression occurs prior to attentional capture, consistent with the proactive control mechanisms (Wang & Theeuwes, 2018; Gaspelin, Leonard, & Luck, 2015).

In summary, the present findings highlight several key insights. First, both simple and complex distractors robustly capture attention, confirming that attentional control is continually challenged by salient stimuli. Second, emotionally salient distractors, particularly negative ones, exert stronger and more persistent interference than simple physical distractors. Finally, statistical learning supports proactive suppression of distractors, even when they carry emotional value, though such suppression is less efficient when stimuli are complex and novel. By integrating behavioral and eye-tracking measures, this work demonstrates that attentional control is both flexible and experience-dependent, dynamically shaped by the interaction between salience, emotion, and learning.

Clinical Significance

The mechanisms governing the suppression of emotional attentional capture extend well beyond the laboratory, carrying direct implications for understanding and treating clinical conditions characterized by dysregulated emotional processing. Disorders such as anxiety, phobias, depression, and post-traumatic stress disorder (PTSD) are consistently associated with a heightened allocation of attentional resources to negative emotional information, which in turn disrupts everyday functioning. This increased attentional capture often makes it difficult to disengage from emotionally salient stimuli, reflecting an impaired interplay between attentional capture and suppression mechanisms.

Numerous studies have demonstrated that attentional orienting is differentially modulated by emotional stimuli. Emotional activation and attentional biases have been extensively studied in various clinical and subclinical populations, including individuals with specific phobias (Carlsson et al., 2004; Miltner et al., 2005; Trippe et al., 2007), survivors of sexual abuse (Grégoire et al., 2018), patients with PTSD (Cisler et al., 2011; Javanbakht et al., 2011; Saar-Ashkenazy et al., 2015), clinically and non-clinically anxious individuals (Williams et al., 1988; Mathews & Mackintosh, 1998; Koster et al., 2006), and individuals with social phobia (Mogg, Philippot, & Bradley, 2004). Across these populations, a convergent pattern emerges which is that threat-relevant stimuli are detected more rapidly, held in attention for longer, and prove more resistant to voluntary disengagement than emotionally neutral counterparts.

For example, Grégoire and colleagues (2018) investigated how exposure to sexual abuse alters the early processing of emotional words by comparing sexual abuse survivors with control participants. Their findings revealed shorter response times to abuse-related stimuli in the survivors' group, indicating greater attention allocation and enhanced attentional prioritization of trauma-related information compared to the control group. Critically, this bias appeared to operate at early, automatic stages of emotional word processing, consistent with the view that repeated exposure to highly aversive events can recalibrate the attentional system's sensitivity thresholds through experience-dependent plasticity, without requiring conscious awareness (Dehaene, 2014). This aligns directly with the present findings: just as statistical learning shaped spatial suppression in healthy participants, prior traumatic experience may similarly reshape attentional priorities, but in a dysfunctional direction, amplifying capture rather than facilitating suppression.

Similarly, Williams and colleagues (1988) demonstrated that clinically anxious individuals show automatic attentional orienting toward threatening stimuli, a finding subsequently extended by Armstrong and Olatunji (2012), who reported both faster orienting toward negative stimuli and greater difficulty disengaging from them. Notably, this difficulty in disengagement mirrors the persistent interference observed for negative picture distractors in the present study, suggesting a mechanistic parallel: in anxious individuals, the suppression mechanisms that healthy participants deploy, however partially, to counteract emotional capture may be further attenuated or fail to develop through experience. This interpretation is consistent with evidence that negative stimuli sustain attentional engagement for longer durations in anxious, trauma-exposed, and subclinical high-anxiety groups relative to controls (Morel et al., 2014).

Attentional biases toward motivationally salient stimuli are not confined to threat-related disorders. In addictive behaviors, individuals exhibit heightened sensitivity to substance-related cues, with faster probe detection when probes replace substance-related rather than neutral stimuli, a pattern commonly assessed via the Posner cueing paradigm (Field & Cox, 2008). The shared structure of these biases across anxiety, trauma, and addiction suggests a domain-general mechanism: stimuli that have acquired high motivational value through experience, whether through repeated trauma, conditioned fear, or reward associations, are assigned elevated priority within the attentional system, making them harder to suppress and easier to capture by. This framing connects the clinical literature directly to the value-driven and selection history accounts discussed earlier and underscores the translational relevance of the present findings.

Taken together, these observations support the view that early, largely automatic processing mechanisms contribute to amplified and persistent attentional biases in individuals with histories of repeated exposure to emotionally significant stimuli. Critically, these biases are not static traits but experience-dependent adaptations, shaped by prior encounters with specific stimuli, contexts, and outcomes (Chelazzi & Santandrea, 2018; Aru et al., 2016), and governed by temporal dynamics that unfold across both short and extended timescales (Cohen et al., 2014). Understanding precisely where and why proactive suppression fails in clinical populations may therefore offer a mechanistic account of attentional bias maintenance, and ultimately inform targeted interventions aimed at restoring the balance between emotional capture and cognitive control.

Future Directions

The overarching aim of this research is to achieve a comprehensive understanding of the neurocognitive mechanisms and neural substrates that confer a special status to emotional stimuli, both in terms of their sensory representations and their privileged access to attentional and motor systems. To investigate these processes, ongoing research combines electroencephalography (EEG) with eye tracking, allowing for the simultaneous assessment of neural dynamics and covert attentional behavior.

A central focus of the EEG analyses is on event-related potential (ERP) components which are assumed to reflect attentional selection and suppression: the N2pc and Pd (distractor positivity) components, respectively. The N2pc, a negative-going component observed contralaterally at posterior scalp sites, is widely referred as an index of attentional selection and is typically observed contralateral to the attended stimulus (Mazza, Turatto, & Caramazza, 2009). In the present context, increased N2pc amplitudes are expected when emotionally salient distractors capture attention, particularly when salient distractors are lateralized relative to the target, reflecting enhanced attentional allocation toward motivationally significant stimuli.

In contrast, the Pd is a contralateral positive-going component observed at posterior sites and is thought to reflect spatial suppression of task-irrelevant stimuli, especially at locations where distractors are likely to appear (Hickey, McDonald, & Theeuwes, 2006; Geng & Behrmann, 2005; Ferrante et al., 2018). The Pd is therefore considered an index of attentional priority regulation and proactive suppression. In the present context, larger Pd amplitudes are predicted for emotional compared to neutral distractors, reflecting the greater cognitive resources required to suppress emotionally salient, yet task-irrelevant, stimuli (Wang et al., 2019; Li, Liu, & Hu, 2018). Specifically, Pd activity contralateral to the distractor is expected to follow N2pc activity when emotional distractors appear at low-probability locations, as well as when targets appear at high-probability distractor locations. This pattern would indicate the engagement of proactive suppression mechanisms shaped by statistical learning.

It is important to note that the effects of emotional stimuli are most commonly observed in later ERP components, particularly the P300 and the Late Positive Potential (LPP), which are widely regarded as indices of the motivational significance and sustained processing of emotionally relevant information (Schupp et al., 2000; Ferrari et al., 2011). By contrast, considerably less is known about how emotional salience influences earlier attentional mechanisms indexed by the N2pc and Pd components. Examining these components therefore provides a unique opportunity to determine whether emotional stimuli affect not only later stages of stimulus evaluation but also the processes of attentional selection and suppression that occur at earlier stages of information processing.

Importantly, previous research has shown that reductions in behavioral interference do not necessarily imply diminished emotional processing (Ferrari et al., 2011; Codispoti et al., 2016). According to this view, neurocognitive mechanisms and behavioral responses may reflect distinct facets of emotional information processing. Consequently, improvements in task performance may coexist with sustained neural responses to emotional stimuli. The probable dissociation highlights the importance of combining behavioral, electrophysiological, and oculomotor measures to fully capture the complexity of emotional information processing and its impact on visual selective attention.

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APPENDIX

Figure List

Figure 1: Illustrative Example of a Salient Stimulus

Figure 2. a) Russell’s circumplex model of affect (1980), which represents emotions along two continuous dimensions: valence (pleasant–unpleasant) and arousal (calm–alert); b) Bradley et al.’s vector model of emotion (1992), which conceptualizes emotions as vectors showing how arousal varies with valence, emphasizing stronger arousal for more extreme (positive or negative) emotions.

Figure 3: Illustration of the Example Salient Stimuli Used in the Experimental Paradigm

Figure 4. Experimental design of Experiment 1. Each trial began with the activation of the eye tracker, and once participants fixated at the center of the display, a fixation cross appeared for a random duration. A picture from the dataset was then presented either to the right or left of the fixation cross at a distance of 7 ° from the center. After one second, the Valence, Arousal, Complexity, and Recognizability scales appeared in sequence, and participants were asked to provide their ratings using the number keys on the keyboard.

Figure 5: Mean Ratings for the pictures across different dimensions: a) Valence scale, b) Arousal scale, c) Complexity scale, d) Recognizability scale

Figure 6. Experimental design for Experiments 2 and 3. Each trial began with the activation of the eye tracker, and once participants fixated at the center of the display, a fixation cross appeared for a randomized duration between 340 and 640ms. Four stimuli were then presented, evenly spaced around an imaginary circle with a radial distance of 7° centered on the fixation cross. Participants were asked to locate the target, which had a distinct outline shape, and indicate whether the white dot appeared above or below it. Displays included either simple geometric shapes or pictures, and a salient distractor was present in 60% of the trials.

Figure 7. Attentional capture effect for different performance measures. A) Accuracy, B) Reaction Time, and C) Inverse Efficiency Score for distractor-absent and distractor-present trials. The figure illustrates how the presence of a distractor affected performance, with lower accuracy, slower responses, or higher inverse efficiency indicating attentional capture by the salient distractor. Significance levels are indicated as $p < .05$ (*), $p < .01$ (**), and $p < .001$ (***).

Figure 8. Practice effect for different performance measures. A) Accuracy, B) Reaction Time, and C) Inverse Efficiency Score for distractor-absent and distractor-present trials across Blocks.

Figure 9. Attentional capture effect for different performance measures. A) Accuracy, B) Reaction Time, and C) Inverse Efficiency Score for distractor-absent and distractor-present trials. Significance levels are indicated as p < .05 (*), p < .01 (**), and p < .001 (***).

Figure 10. Practice effect for different performance measures. A) Accuracy, B) Reaction Time, and C) Inverse Efficiency Score for distractor-absent and distractor-present trials across Blocks.

Figure 11. Regression analysis between valence and behavioral performance. Each point represents a participant's average, and the regression line indicates the overall trend. The figure shows how performance varied as a function of stimulus valence. A positive slope in accuracy (A) indicates better performance for neutral stimuli, while a negative slope in reaction time (B) indicates slower responses as stimuli become more negative.

Figure 12. Distribution of first saccade landings across the stimulus display.

Figure 13. Attentional capture effect for different performance measures. A) Accuracy, B) Reaction Time, and C) Inverse Efficiency Score for distractor-absent and distractor-present trials. Significance levels are indicated as p < .05 (*), p < .01 (**), and p < .001 (***).

Figure 14. Practice effect for different performance measures. A) Accuracy, B) Reaction Time, and C) Inverse Efficiency Score for distractor-absent and distractor-present trials across Blocks.

Figure 15. Statistical Learning effect for different performance measures. A) Accuracy, B) Reaction Time, and C) Inverse Efficiency Score for high-probability and low-probability distractor locations. Significance levels are indicated as p < .05 (*), p < .01 (**), and p < .001 (***).

Figure 16. Practice effect and statistical learning regularities for different performance measures. A) Accuracy, B) Reaction Time, and C) Inverse Efficiency Score for high-probability and low-probability distractor locations across Blocks.

Figure 17. Attentional capture for different performance measures. A) Accuracy, B) Reaction Time, and C) Inverse Efficiency Score for distractor-present and distractor-absent trials. Significance levels are indicated as p < .05 (*), p < .01 (**), and p < .001 (***).

Figure 18. Practice effect for different performance measures. A) Accuracy, B) Reaction Time, and C) Inverse Efficiency Score for distractor-present and distractor-absent trials across Blocks.

Figure 19. Statistical Learning effect for different performance measures. A) Accuracy, B) Reaction Time, and C) Inverse Efficiency Score for high-probability and low-probability distractor locations. Significance levels are indicated as p < .05 (*), p < .01 (**), and p < .001 (***).

Figure 20. Statistical Learning effect for different performance measures. A) Accuracy, B) Reaction Time, and C) Inverse Efficiency Score for target presented at high- and low-probability distractor locations. Significance levels are indicated as $p < .05$ (*), $p < .01$ (**), and $p < .001$ (***).

Figure 21. Practice effect and statistical regularities for different performance measures. A) Accuracy, B) Reaction Time, and C) Inverse Efficiency Score for high-probability and low-probability distractor locations across Blocks.

Figure 22. Regression analysis between valence and behavioral performance. Each point represents a participant's average, and the regression line indicates the overall trend. The figure shows how performance varied as a function of stimulus valence. A positive slope in accuracy (A) indicates better performance for neutral stimuli, while a negative slope in reaction time (B) indicates slower responses as stimuli become more negative.

Figure 23. Distribution of first saccade landings across the stimulus display.

Table 1. Overview of picture stimuli included in the final dataset, with corresponding mean ratings of arousal, valence, recognizability, and complexity, along with category, dataset, and source information.

Emotion	*Description*	*Code*	*Arousal (M)*	*Valence (M)*	*Recognizability (M)*	*Complexity (M)*	*Category*	*Dataset*	*Source*
negative	dead child	1	4.2	2	5.2	5	social	distractor	EmoPics
negative	soldiers	2	5.4	2.5	7.2	4.7	social	distractor	OASIS
negative	surgery	3	4.8	2.5	5.4	4.5	social	distractor	OpenSource
negative	dead child	4	5.4	2	7.4	4.5	social	distractor	EmoPics
negative	stabbed man	5	4.6	2.5	4.8	5.2	social	distractor	OpenSource
negative	injury	6	4.2	2.1	6.1	3.9	social	distractor	OpenSource
negative	mutilation	7	4.7	2.1	8.2	3.1	social	distractor	OpenSource
negative	injury	8	5.2	1.3	7	5.4	social	distractor	OpenSource
negative	mutilation	9	6	1.5	7.5	3.8	social	distractor	OpenSource
negative	mutilation	10	5.1	1.4	7	5.4	social	distractor	OpenSource
negative	riot injury	11	4.2	2.5	6.7	4.9	social	distractor	OpenSource
negative	mutilation	12	4.1	2.5	5.1	3.7	social	distractor	OpenSource
negative	burned child	13	3.9	2	6.5	4.2	social	distractor	EmoPics
negative	burned child	14	4.3	1.2	5.2	4.9	social	distractor	EmoPics
negative	injury	15	3.6	2.2	6.9	3.5	social	distractor	OASIS
negative	eye tumor	16	5	2.1	5.1	3.9	social	distractor	OASIS
negative	burned legs	17	5	1.4	6.1	4.8	social	distractor	IAPS
negative	injection	18	4.2	2.7	8.1	3.2	social	distractor	OASIS
negative	tortured people	19	4.5	1.9	6.5	4.8	social	distractor	OpenSource
negative	mutilation	20	4.7	2.3	6	5.7	social	distractor	OpenSource
negative	mutilation	21	4.9	1.6	6.5	4.5	social	distractor	IAPS
negative	mutilation	22	5.5	1.7	6.7	4.5	social	distractor	OpenSource
negative	incident	23	4.8	1.9	5.7	6.8	social	distractor	OpenSource
negative	dead bodies	24	3.9	2.5	7.1	5.3	social	distractor	OASIS
negative	mutilation	25	5.2	1.3	5.7	5.7	social	distractor	OpenSource
negative	mutilation	26	4.8	1.5	6.6	4.3	social	distractor	OpenSource
negative	mutilation	27	4.8	1.9	6.8	3.6	social	distractor	OpenSource
negative	tortured man	28	4.9	1.7	7.8	3	social	distractor	OpenSource
negative	surgery	29	4.4	1.9	6	4.3	social	distractor	OpenSource
negative	tortured child	30	4.8	1.7	6.4	4.5	social	distractor	GAPED
negative	injury	31	5	1.9	7.3	4.5	social	distractor	OASIS
negative	injury	32	4.3	1.9	6.6	4.3	social	distractor	OpenSource
negative	mutilation	33	4.9	1.6	6.6	5	social	distractor	OpenSource
negative	disease	34	4.9	2.3	7.8	3.5	social	distractor	OpenSource
negative	mutilation	35	3.9	1.9	7.8	2.9	social	distractor	OpenSource
negative	burned child	36	5.4	2	5.4	4.6	social	distractor	OpenSource
negative	mutilation	37	4.4	2.3	6.5	3.7	social	distractor	OpenSource
negative	tortured man	38	3.8	2.4	5.9	3.1	social	distractor	OpenSource
negative	hanged man	39	5.7	2.7	6	5.6	social	distractor	IAPS
negative	stabbed feet	40	5.1	1.9	6.5	4.8	social	distractor	OpenSource
negative	surgery	41	5.1	2.1	5.8	5.2	social	distractor	IAPS
negative	child holding gun	42	4.7	2.3	7.6	2.9	social	distractor	IAPS
negative	dead man	43	5.1	1.9	5.9	5.1	social	distractor	IAPS
negative	gun violence	44	3.4	2.9	6.9	3.4	social	distractor	IAPS
negative	riot	45	3.6	2.7	6.7	4.6	social	distractor	OpenSource
negative	malnourished child	46	4.1	2.3	5	3.4	social	distractor	IAPS
negative	deteriorated teeth	47	3.3	3.2	8.4	3.3	social	distractor	IAPS
negative	disease	48	4	2.2	6.1	3.3	social	distractor	OpenSource
negative	fire	49	4.5	1.9	5.9	5.8	social	distractor	OpenSource

negative	insect consumption	50	6.1	1.8	7.4	4.8	social	distractor	OpenSource
negative	mutilation	51	4.6	1.5	7.6	3.9	social	distractor	OpenSource
negative	injection	52	4	3	8	3	social	distractor	OASIS
negative	burned man	53	3.3	1.9	7.4	2.8	social	distractor	OpenSource
negative	disease	54	4.4	1.6	7	4	social	distractor	OpenSource
negative	injury	55	2.9	2.6	7.4	3.1	social	distractor	OpenSource
negative	hostages	56	4.7	2.3	5	6.3	social	distractor	IAPS
negative	breast tumor	57	5.1	1.1	6.9	4.6	social	distractor	IAPS
negative	mutilation	58	4.7	1.7	4.6	5.6	social	distractor	IAPS
negative	soldier	59	3.5	2.5	8	3.5	social	distractor	OpenSource
negative	tumor	60	5.4	1.9	4.5	4.9	social	distractor	IAPS
negative	war zone	61	4.6	1.9	7.6	5.9	social	distractor	OpenSource
negative	destroyed building	62	3.6	2.3	6.4	5.5	social	distractor	OpenSource
negative	dead child	63	3.7	2.1	4.2	5.4	social	distractor	OpenSource
negative	burned man	64	5	1.6	5.2	4.9	social	distractor	OpenSource
negative	gun violence	65	3.6	2.4	7.1	4.7	social	distractor	OpenSource
negative	mutilation	66	5.1	1.1	7.8	3.9	social	distractor	OpenSource
negative	mutilation	67	4.6	1.7	5	5.9	social	distractor	OpenSource
negative	riot	68	4.3	1.9	5.5	5.7	social	distractor	OpenSource
negative	mutilation	69	5.8	1.8	6.2	3.9	social	distractor	OpenSource
negative	earthquake damage	70	3.9	2.5	4.4	5.8	social	distractor	OpenSource
negative	surgery	71	4.8	2.1	5	6.1	social	distractor	OpenSource
negative	surgery	72	5.2	2.2	6	4.8	social	distractor	OpenSource
negative	surgery	73	5.2	2	7.5	4.2	social	distractor	OpenSource
negative	hostages	74	4.1	2.7	5.6	5.8	social	distractor	OpenSource
negative	earthquake damage	75	3.8	2	7.1	5.6	social	distractor	OpenSource
negative	mutilation	76	5.3	1.5	6.8	4.7	social	distractor	OpenSource
negative	fire	77	4	2.6	7.8	4.7	social	distractor	OpenSource
negative	deteriorated teeth	78	3.9	2.9	7.3	3.7	social	distractor	OpenSource
negative	deteriorated teeth	79	4.4	1.9	8.1	3.5	social	distractor	OpenSource
negative	stitches	80	4.2	2.5	7.6	3.9	social	distractor	OpenSource
negative	riot / fire	81	4.4	1.9	6.3	5	social	distractor	OpenSource
negative	violence	82	3.8	2.9	5.6	4.6	social	distractor	OpenSource
negative	mutilation	83	4.5	1.8	6.1	3.7	social	distractor	OpenSource
negative	skull	84	3.5	2.6	6.9	2.8	social	distractor	OpenSource
negative	violence / hostage	85	3.8	2.3	5.8	4.2	social	distractor	OpenSource
negative	burned arm	86	5.3	1.9	5.7	4.9	social	distractor	OpenSource
negative	stitches	87	3.7	1.9	7.2	3.2	social	distractor	OpenSource
negative	injury	88	3.9	1.6	7.9	3.2	social	distractor	OpenSource
negative	severely malnourished	89	4.1	2.8	5.6	4	social	distractor	OpenSource
negative	insect	90	4	2.7	5.8	3.6	social	distractor	OpenSource
negative	incident	91	4.6	2.8	7.3	4.8	social	distractor	OpenSource
neutral	a woman	1	3.9	5.7	6.6	4.3	social	distractor	OpenSource
neutral	hand	2	3.1	5.8	5.5	6.1	social	distractor	OpenSource
neutral	metro stairs	3	3.1	4.9	6.7	6.6	social	distractor	EmoPics
neutral	foot	4	3.1	3.9	5.5	4.9	social	distractor	IAPS
neutral	runner	5	3.1	5.3	8.1	2.8	social	distractor	IAPS
neutral	golf player	6	3.7	5.9	5.7	4.4	social	distractor	IAPS
neutral	man	7	2.5	5.3	7.7	3.2	social	distractor	OpenSource
neutral	people on the street	8	2.7	5.4	7.3	5.1	social	distractor	OpenSource
neutral	feet	9	3.2	5.7	7.8	3.1	social	distractor	OpenSource
neutral	bus station	10	2.8	5.2	6.8	5.5	social	distractor	OpenSource
neutral	bus station	11	2.9	5.4	7.4	3.4	social	distractor	OpenSource
neutral	worker	12	2.3	5.6	7.4	4.8	social	distractor	EmoPics
neutral	library	13	3.8	5.8	5.9	6.6	social	distractor	EmoPics
neutral	gardener	14	2.2	5.4	4.8	5.5	social	distractor	EmoPics
neutral	archery	15	2.9	5.9	6.8	4.4	social	distractor	OASIS

neutral	hands on keyboard	16	3	5.6	8.1	2.2	social	distractor	OpenSource
neutral	parking area	17	2.9	5.3	6.9	5.6	social	distractor	OpenSource
neutral	legs	18	2.1	6	7.6	3.5	social	distractor	OpenSource
neutral	legs	19	2.7	5.7	6.3	5.1	social	distractor	OpenSource
neutral	bus	20	2.7	4.7	8.4	4.9	social	distractor	OpenSource
neutral	people	21	2.7	5.3	5.3	5.6	social	distractor	GAPED
neutral	painter	22	2.8	4.9	4.2	5.6	social	distractor	OpenSource
neutral	a woman	23	3.6	5.4	7	4.1	social	distractor	OpenSource
neutral	a man	24	3.7	5.6	6.2	5.4	social	distractor	GAPED
neutral	rafting	25	2.9	5.3	6.5	4.5	social	distractor	OpenSource
neutral	bus station	26	2.9	4.8	7.4	4.1	social	distractor	OpenSource
neutral	woman	27	3.1	5.9	5.6	4.4	social	distractor	EmoPics
neutral	waiting room	28	2.8	5	5.8	5.4	social	distractor	OpenSource
neutral	people on the street	29	1.6	5.5	6.9	4.3	social	distractor	OpenSource
neutral	people on the street	30	3.1	5.7	6.5	6.6	social	distractor	EmoPics
neutral	people on the street	31	3.5	5.3	5.6	5.8	social	distractor	EmoPics
neutral	legs	32	2.2	5.4	6.9	3.8	social	distractor	OpenSource
neutral	man reading	33	3.3	5.6	5.8	4.6	social	distractor	EmoPics
neutral	people on the street	34	3.9	4.9	5.1	5.9	social	distractor	EmoPics
neutral	worker	35	1.9	4.7	6.7	4.1	social	distractor	OpenSource
neutral	train station	36	3.2	4.7	6.3	5.7	social	distractor	OpenSource
neutral	train station	37	3.4	4.9	6.4	6.1	social	distractor	OpenSource
neutral	hands	38	3.3	5.5	7	4	social	distractor	OpenSource
neutral	people in the office	39	3.4	4.8	7.6	5.1	social	distractor	EmoPics
neutral	people doing graffiti	40	4.2	4.5	4.7	5.4	social	distractor	EmoPics
neutral	people at line	41	1.8	5.1	6.3	5.4	social	distractor	EmoPics
neutral	people at line	42	2.9	5.1	6.5	5.2	social	distractor	EmoPics
neutral	man	43	2.1	5.1	5.4	4.5	social	distractor	EmoPics
neutral	woman	44	2.5	5.8	7.4	4	social	distractor	EmoPics
neutral	woman	45	2.5	5	5.6	3.9	social	distractor	IAPS
neutral	legs	46	2.7	4.9	6.6	4	social	distractor	OpenSource
neutral	legs	47	3.2	5.2	6.1	3.8	social	distractor	OpenSource
neutral	child	48	3	5.2	6.4	3.2	social	distractor	IAPS
neutral	people on the street	49	3.7	6.2	7	5.8	social	distractor	OpenSource
neutral	man	50	2.6	5.1	5.3	4.1	social	distractor	IAPS
neutral	woman	51	2.8	5.7	5.8	3.1	social	distractor	IAPS
neutral	people on the street	52	2.8	5.6	5.8	4.8	social	distractor	OpenSource
neutral	waiting room	53	2.8	5.2	7	4.9	social	distractor	OpenSource
neutral	people at the café	54	3.4	5.9	7.8	6.1	social	distractor	OpenSource
neutral	legs	55	2.4	4.6	5.4	3.1	social	distractor	OpenSource
neutral	board game	56	2.8	6	5.2	5.7	social	distractor	OpenSource
neutral	man	57	2.8	5.2	6.1	3.5	social	distractor	OpenSource
neutral	worker	58	2.3	5.4	7.5	4.6	social	distractor	OpenSource
neutral	worker	59	2.1	5.2	7.1	4.9	social	distractor	OpenSource
neutral	man running	60	2.9	5.6	7.1	4.2	social	distractor	OpenSource
neutral	legs	61	3.6	5.3	7.8	3	social	distractor	OpenSource
neutral	worker	62	2.5	4.9	5.5	6.4	social	distractor	OpenSource
neutral	worker	63	2.7	4.5	5.1	6.2	social	distractor	OpenSource
neutral	anklet	64	1.9	5.1	5.6	3.8	social	distractor	Things
neutral	people on the street	65	3	5.4	6.9	5.6	social	distractor	OpenSource
neutral	bracelet	66	1.9	5.5	6.5	3.6	social	distractor	Things
neutral	calf	67	3.8	5.9	7.9	2.6	social	distractor	Things
neutral	holding camera lens	68	3.5	5.5	7.9	2.6	social	distractor	Things
neutral	holding camera	69	3.1	5.5	7	3.3	social	distractor	Things
neutral	playing with clay	70	2.7	5.7	6.5	3.7	social	distractor	Things
neutral	holding drill	71	3.1	4.3	5.3	3.4	social	distractor	Things
neutral	elbow	72	2.1	5.1	6.7	2.9	social	distractor	Things

neutral	hands	73	2.6	5.2	6.5	3.4	social	distractor	Things
neutral	worker	74	2.8	4.2	4.5	5.2	social	distractor	Things
neutral	hula hoops	75	3.6	5.8	7.5	5	social	distractor	Things
neutral	kneepad	76	2.8	4.2	4.2	4.4	social	distractor	Things
neutral	woman	77	3.1	5.4	7.3	3.5	social	distractor	Things
neutral	people in the office	78	3	4.9	7.5	4.8	social	distractor	OpenSource
neutral	woman	79	3.3	5.2	5.8	4.1	social	distractor	Things
neutral	worker	80	2.6	4.9	4.6	4.5	social	distractor	Things
neutral	feet	81	2.9	5.1	7.1	3.8	social	distractor	Things
neutral	worker	82	2.6	4.6	6.9	3.9	social	distractor	EmoPics
neutral	student	83	3.4	4.9	7.9	3.8	social	distractor	Things
neutral	worker	84	2.6	4.2	7.3	3.4	social	distractor	OpenSource
neutral	harness	85	2.1	4.9	5.9	4.4	social	distractor	Things
neutral	worker	86	2.9	4.4	6.2	4.6	social	distractor	Things
neutral	gardener	87	2	5.1	6.5	4.2	social	distractor	Things
neutral	legs	88	1.8	5.4	8.2	2.5	social	distractor	Things
neutral	hands	89	3.1	5.1	5.2	3.7	social	distractor	Things
neutral	woman	90	2.9	5.5	8.2	4.7	social	distractor	OpenSource
neutral	playing cards	91	3.5	5.2	7.9	3.7	social	distractor	Things
neutral	a woman shopping	1	2.2	4.8	5.5	5.2	social	filler	OpenSource
neutral	bow	2	2.5	5.8	7	3.3	social	filler	Things
neutral	train station	3	3.5	4.7	6.6	5.3	social	filler	OpenSource
neutral	hands on a computer	4	2.8	5.7	8	2.7	social	filler	OpenSource
neutral	painter	5	2.9	6	5.2	4.7	social	filler	OpenSource
neutral	a man crossing street	6	3.1	5.2	7.3	6.9	social	filler	OpenSource
neutral	a woman on the street	7	3.1	5.8	5.9	6.3	social	filler	EmoPics
neutral	a woman on the street	8	3	4.8	5	4.7	social	filler	EmoPics
neutral	golf player	9	2.6	5.5	8.5	3.2	social	filler	IAPS
neutral	legs	10	3.5	5.6	8	2.6	social	filler	OpenSource
neutral	street	11	1.8	5.6	6.4	5.2	social	filler	EmoPics
neutral	a woman	12	3.3	5.2	3.4	6.6	social	filler	IAPS
neutral	a man	13	2.8	5.5	7.7	3.5	social	filler	IAPS
neutral	a man with a dog	14	2.7	4.9	5.9	4	social	filler	IAPS
neutral	painting	15	2.7	4.5	5.1	3.9	social	filler	IAPS
neutral	chess	16	4.4	6.2	8.3	3.2	social	filler	IAPS
neutral	a man	17	3.8	4.1	6.7	4.1	social	filler	OpenSource
neutral	street	18	3.9	5.6	8	5.6	social	filler	OpenSource
neutral	a woman	19	2.7	5.5	8.5	2.9	social	filler	Things
neutral	cooking	20	3.4	5	5.3	5	social	filler	OpenSource
neutral	street	21	3.1	5.3	6.5	5.4	social	filler	OpenSource
neutral	man	22	3.1	4.6	7.9	2.9	social	filler	OpenSource
neutral	worker	23	2.4	4.9	7.2	4.2	social	filler	OpenSource
neutral	table game	24	2.9	6.1	6.4	5.6	social	filler	OpenSource
neutral	bus station	25	2.9	5.6	6.1	4.9	social	filler	OpenSource
neutral	man	26	3.3	4.3	7.1	4.3	social	filler	OpenSource
neutral	shoelace	27	3.5	5	6.8	3.7	social	filler	OpenSource
neutral	wheelbarrow	28	2.3	5.1	8.3	2.8	social	filler	Things
neutral	woman	29	2.3	5.7	8.3	2.7	social	filler	Things
neutral	curling iron	30	2.3	5.6	5.8	4.7	social	filler	Things
neutral	an ear	31	2.4	4.9	7.8	2.2	social	filler	Things
neutral	a hand	32	3.1	4.6	5.8	4.1	social	filler	Things
neutral	woman	33	2.7	5.5	7.1	3.4	social	filler	Things
neutral	knee	34	3.1	4	6.5	2.4	social	filler	Things
neutral	woman	35	2.4	5.4	7.3	3.4	social	filler	Things
neutral	chef	36	2.9	5.3	5.1	4.5	social	filler	OpenSource
neutral	rafting	37	3.6	5.3	7.1	3.7	social	filler	Things
neutral	people with raincoat	38	3.3	5.9	7.4	5.1	social	filler	Things

neutral	roller skate	39	2.4	5.3	7.6	3.2	social	filler	Things
neutral	spark plug	40	2	4.8	5.1	4.6	social	filler	Things
neutral	a hand	41	2.6	4.9	3.9	5.7	social	filler	Things
neutral	man	42	2.2	4.8	7.2	2.6	social	filler	Things
neutral	hair	43	2.8	6.2	7.2	3.3	social	filler	Things
neutral	holding lens	44	2.3	4.6	3.9	4.2	social	filler	Things
neutral	a woman and a dog	45	1.9	6	8	2.9	social	filler	EmoPics
neutral	a road	46	2.7	4.7	8.1	4.8	non-social	filler	OpenSource
neutral	branches	47	2.3	5.3	7.4	3.4	non-social	filler	OpenSource
neutral	plant	48	3.4	5.3	5.1	4.9	non-social	filler	EmoPics
neutral	ostrich	49	2.7	6.2	8.5	2.1	non-social	filler	EmoPics
neutral	a car	50	3.3	4.9	4.1	5.7	non-social	filler	EmoPics
neutral	camels	51	2.7	5.5	7	4.7	non-social	filler	EmoPics
neutral	a moose	52	1.8	5.3	7.3	2.7	non-social	filler	EmoPics
neutral	rhinos	53	3.7	5.1	6.7	4.5	non-social	filler	EmoPics
neutral	a geco	54	2	5.2	7.2	2.3	non-social	filler	EmoPics
neutral	weed	55	2.7	5.6	6.6	4.6	non-social	filler	EmoPics
neutral	a plant	56	3.6	5.9	6.8	3.6	non-social	filler	IAPS
neutral	shell and mushrooms	57	2	5.1	3.3	5.3	non-social	filler	IAPS
neutral	empty road	58	3.4	6.1	6.9	3.7	non-social	filler	IAPS
neutral	tools	59	3	4.9	7.7	4.1	non-social	filler	IAPS
neutral	wooden baskets	60	2.4	5	6.8	3.9	non-social	filler	IAPS
neutral	road	61	2.5	5.4	7.1	4.5	non-social	filler	OpenSource
neutral	scarf	62	2.5	5.2	4.8	5.4	non-social	filler	IAPS
neutral	bird	63	2.9	5.6	6.2	4.9	non-social	filler	OpenSource
neutral	office supplies	64	2.8	5.1	8.2	3.7	non-social	filler	OASIS
neutral	cherries	65	3.6	5.8	7.3	3.3	non-social	filler	GAPED
neutral	car road	66	2.5	5.7	7.9	4.4	non-social	filler	OpenSource
neutral	pine cone	67	2.7	5.8	7.4	4.1	non-social	filler	OASIS
neutral	pine cone	68	1.7	5.2	5.5	3.5	non-social	filler	OASIS
neutral	power lines	69	3.1	6.1	8.4	3.7	non-social	filler	OASIS
neutral	flowers	70	2.1	6.1	5.9	5.4	non-social	filler	IAPS
neutral	yarn	71	2.5	5.1	6.1	2.7	non-social	filler	OASIS
neutral	bird	72	3	6	7.2	3.2	non-social	filler	OpenSource
neutral	tree	73	2.4	5.4	7.5	3.2	non-social	filler	OpenSource
neutral	weed	74	2.5	5.5	7.1	3.5	non-social	filler	EmoPics
neutral	mushrooms	75	2.7	5.8	7.9	2.9	non-social	filler	EmoPics
neutral	buffalo	76	3.1	5.4	7.1	4.3	non-social	filler	EmoPics
neutral	wooden crates	77	2.7	5.1	3.7	5.9	non-social	filler	Things
neutral	cows	78	3	5.9	7.8	4.8	non-social	filler	EmoPics
neutral	monkey	79	2.9	5.8	5.6	4.1	non-social	filler	EmoPics
neutral	weed	80	1.9	5.9	6	3.9	non-social	filler	EmoPics
neutral	weed	81	2.8	5	6.8	3.3	non-social	filler	EmoPics
neutral	ship	82	2.7	4.8	6.1	4.6	non-social	filler	IAPS
neutral	buttons	83	2.4	5.4	7.6	5.6	non-social	filler	IAPS
neutral	container	84	2.2	4.3	7.9	2.3	non-social	filler	IAPS
neutral	bark	85	2.4	5.2	6.7	3.9	non-social	filler	OASIS
neutral	cotton swabs	86	2.5	4.8	7.2	3.4	non-social	filler	OASIS
neutral	fire hydrant	87	2.9	4.9	7.1	3.3	non-social	filler	OASIS
neutral	squirrel	88	2.3	5.2	3.1	3.9	non-social	filler	OpenSource
neutral	paper clips	89	3.6	6.2	8.1	5.8	non-social	filler	OASIS
neutral	pigeon	90	2.8	4.5	7.1	3.1	non-social	filler	OASIS
neutral	soccer ball	91	3.2	5.2	5.6	3.6	non-social	filler	OASIS
neutral	stingray	92	4.2	3.8	4.9	3.9	non-social	filler	OASIS
neutral	plastic crates	93	2.1	4.8	6.6	5.9	non-social	filler	OASIS
neutral	street	94	3	5.1	7.4	4.2	non-social	filler	OpenSource
neutral	monkey	95	2.8	5.7	6.1	3.6	non-social	filler	OpenSource

neutral	chickens	96	2	4.9	5.6	4.9	non-social	filler	EmoPics
neutral	cow	97	2.1	4.1	7.4	2.5	non-social	filler	EmoPics
neutral	crow	98	3.1	5.4	7.8	2.7	non-social	filler	EmoPics
neutral	plant	99	2.2	5.4	6.8	3.7	non-social	filler	EmoPics
neutral	plant	100	2.5	4.9	6.9	3.8	non-social	filler	EmoPics
neutral	weed	101	2	5.6	7.5	4	non-social	filler	EmoPics
neutral	weed	102	1.9	5.2	7.9	3.2	non-social	filler	EmoPics
neutral	fish	103	3.1	5.8	4.3	6.4	non-social	filler	IAPS
neutral	weed	104	3	6.1	6.7	4.8	non-social	filler	IAPS
neutral	mountain	105	3.2	5.5	3.3	6.1	non-social	filler	IAPS
neutral	car	106	3.2	5.8	4.6	3.9	non-social	filler	IAPS
neutral	ancorns	107	3.2	5.4	5.2	3.7	non-social	filler	OASIS
neutral	dirt	108	2.6	5.1	4.5	5	non-social	filler	OASIS
neutral	fence	109	2.7	4.9	5.2	4.4	non-social	filler	OASIS
neutral	street	110	2.4	5	6.7	4	non-social	filler	OpenSource
neutral	keys	111	2.4	5.2	6.2	6.8	non-social	filler	OASIS
neutral	library	112	2.9	5.7	7.1	3.9	non-social	filler	GAPED
neutral	fish	113	3	5.8	5.1	4.9	non-social	filler	GAPED
neutral	sidewalk	114	2.6	5.5	6.2	3.7	non-social	filler	OASIS
neutral	skyscraper	115	3.3	5.2	7.8	2.4	non-social	filler	OASIS
neutral	soccer ball	116	2.5	5.3	7.7	3.1	non-social	filler	OASIS
neutral	storage	117	2.7	4.3	5.3	5.7	non-social	filler	OASIS
neutral	barrels	118	2.9	4.8	5.3	6.4	non-social	filler	OASIS
neutral	weed	119	2.5	5.1	7	5	non-social	filler	EmoPics
neutral	mushrooms	120	2.1	4.2	5.6	3.2	non-social	filler	EmoPics
neutral	cow	121	2	5.4	8.1	4	non-social	filler	EmoPics
neutral	crow	122	1.9	5.6	7.9	2.8	non-social	filler	EmoPics
neutral	weed	123	2.9	5.8	7.3	3.9	non-social	filler	EmoPics
neutral	weed	124	1.9	5.8	4.9	5.6	non-social	filler	EmoPics
neutral	weed	125	2.5	5.1	6.1	3.9	non-social	filler	EmoPics
neutral	weed	126	2.7	5.2	6	3.9	non-social	filler	EmoPics
neutral	train	127	3.2	5.7	7	4.1	non-social	filler	IAPS
neutral	luggages	128	2.1	5.1	7.9	4.7	non-social	filler	IAPS
neutral	carpet	129	2.3	5.3	6.9	4.6	non-social	filler	IAPS
neutral	window	130	3.5	5.4	4.8	3.8	non-social	filler	IAPS
neutral	stairs	131	2.9	4.8	4.7	5	non-social	filler	IAPS
neutral	rocks	132	2.4	5.2	3.7	6.3	non-social	filler	OpenSource
neutral	bubble	133	3	4.4	3.4	5.8	non-social	filler	OASIS
neutral	squirrel	134	2.9	5.3	4	5.5	non-social	filler	OpenSource
neutral	coton swabs	135	2.5	4.9	5.4	4.9	non-social	filler	OASIS
neutral	soil	136	3.2	4.4	6.9	3.1	non-social	filler	OASIS
neutral	street	137	3.1	5.9	7.3	5	non-social	filler	OpenSource
neutral	bike wheel	138	2.4	5.5	6.9	2.8	non-social	filler	GAPED
neutral	bike	139	2.8	5.2	8.2	2.2	non-social	filler	GAPED
neutral	cables and tubes	140	2.9	4.9	3.4	7.6	non-social	filler	GAPED
neutral	skyscrapers	141	3.7	6.1	7.8	4.9	non-social	filler	OASIS
neutral	stingray	142	3.1	5.6	4.7	4.3	non-social	filler	OASIS
neutral	shoes	143	2.1	4.8	8.5	2.1	non-social	filler	IAPS
neutral	bibelot	144	2.7	5.9	7.3	3.1	non-social	filler	IAPS
neutral	mushrooms	145	2.7	6.3	7.4	3.8	non-social	filler	EmoPics
neutral	fence	146	3	5.1	8.5	3	non-social	filler	OASIS
neutral	fence	147	2.2	5.1	8.2	3.5	non-social	filler	OASIS
neutral	mushroom	148	2.6	5.9	6.9	2.9	non-social	filler	EmoPics
neutral	cactus	149	3.4	5.3	6.7	3.7	non-social	filler	EmoPics
neutral	cactus	150	2.3	5.2	5.4	5.1	non-social	filler	EmoPics
neutral	cactus	151	2.9	5.1	6.8	4.8	non-social	filler	EmoPics
neutral	mushrooms	152	2.4	5.9	8	3.5	non-social	filler	EmoPics

neutral	mushrooms	153	2.8	5.5	4.5	4.5	non-social	filler	EmoPics
neutral	mushrooms	154	2.3	4.9	6	5.1	non-social	filler	EmoPics
neutral	mushrooms	155	2	5.5	7	3.8	non-social	filler	EmoPics
neutral	tram	156	2.1	5.3	7.8	3.9	non-social	filler	Things
neutral	bus station	157	3.5	5.5	7.3	4.1	non-social	filler	OpenSource
neutral	ships	158	3.4	6.1	5.5	5.6	non-social	filler	OpenSource
neutral	ship	159	2.2	5.2	7.7	3.7	non-social	filler	OpenSource
neutral	table game	160	3.1	5.7	6.1	6.4	non-social	filler	OpenSource
neutral	shipping bay	161	1.8	4.6	6.4	5.7	non-social	filler	OpenSource
neutral	painting brushes	162	3.2	5.9	6.8	5.2	non-social	filler	OpenSource
neutral	cointainer house	163	2.9	4.6	6.7	3.7	non-social	filler	OpenSource
neutral	starfish	164	3.1	5	4.5	5	non-social	filler	OpenSource
neutral	drinking fountain	165	2.3	5.5	4	4.5	non-social	filler	Things
neutral	two artichokes	166	2.2	5.5	7	3.2	non-social	filler	Things
neutral	pieces of woods	167	3	4.8	4.1	5.4	non-social	filler	Things
neutral	beads	168	3.3	6.2	6.5	5.8	non-social	filler	Things
neutral	buttons	169	2.4	4.5	7.5	5.9	non-social	filler	Things
neutral	cement mixer	170	1.9	5.1	5.6	2.8	non-social	filler	Things
neutral	shipping bay	171	1.8	4.9	7	5.3	non-social	filler	Things
neutral	curb	172	2	4.8	7.8	3.2	non-social	filler	Things
neutral	speedometer	173	3.4	4.7	7.3	3.6	non-social	filler	Things
neutral	duck	174	3.1	6	8.1	2.7	non-social	filler	Things
neutral	fencepost	175	2.9	5	6.6	4.7	non-social	filler	Things
neutral	timber	176	2.4	5.5	4.4	5.9	non-social	filler	Things
neutral	float	177	2.9	5.3	5.7	4.5	non-social	filler	Things
neutral	golf cart	178	2	4.9	7.6	3.6	non-social	filler	Things
neutral	grapes	179	3.4	5.9	8.1	2.6	non-social	filler	Things
neutral	handlebar	180	2.4	5.5	7.7	2.9	non-social	filler	Things
neutral	ladder	181	2.7	5.7	8.3	2.6	non-social	filler	Things
neutral	lifesaver	182	2.2	5.4	7.6	2.5	non-social	filler	Things
neutral	a truck	183	2.4	5.3	7.5	4.4	non-social	filler	Things
neutral	almonds	184	2.6	5.9	7.6	4.2	non-social	filler	Things
neutral	shovels	185	2.8	5.5	5.1	4.5	non-social	filler	Things
neutral	olives	186	2.6	5.9	7.8	3.2	non-social	filler	Things
neutral	padlock	187	1.9	4.9	5.4	3.3	non-social	filler	Things
neutral	parsley	188	2.4	5.6	7.2	4.5	non-social	filler	Things
neutral	peache	189	2.8	6	8.5	3	non-social	filler	Things
neutral	peanut	190	2.8	5.4	7.8	3.5	non-social	filler	Things
neutral	pincushion	191	3.2	5.1	7.2	4	non-social	filler	Things
neutral	bag	192	2.8	5.9	8.1	2.2	non-social	filler	Things
neutral	quilt	193	3.3	5.8	4.9	5.5	non-social	filler	Things
neutral	rake	194	2.7	5.5	8.1	3.4	non-social	filler	Things
neutral	swiss chards	195	2.8	5.8	6.9	3.9	non-social	filler	Things
neutral	rollerblade	196	2.9	5.5	7.4	2.7	non-social	filler	Things
neutral	tree roots	197	3.3	5	5.9	5.3	non-social	filler	Things
neutral	sail	198	2.9	5.8	4.3	4.6	non-social	filler	Things
neutral	spring onions	199	2.4	5.5	8	4.2	non-social	filler	Things
neutral	scarf	200	3.1	5.5	6.1	4.1	non-social	filler	Things
neutral	scooter	201	2.5	4.8	7	3.1	non-social	filler	Things
neutral	sequin	202	2.5	5.6	5.9	6.4	non-social	filler	Things
neutral	sewing machine	203	1.9	5.5	5.8	3.8	non-social	filler	Things
neutral	soccer ball	204	2.8	5.4	8	2.1	non-social	filler	Things
neutral	stump	205	3	5.4	7.1	3.1	non-social	filler	Things
neutral	terrarium	206	3.7	5.4	6.3	4.4	non-social	filler	Things
neutral	tractor	207	2.1	5.4	8.3	2.6	non-social	filler	Things
neutral	train	208	2.6	5.1	7.3	3.6	non-social	filler	Things
neutral	train car	209	2	5.1	7.9	2.9	non-social	filler	Things

neutral	ship	210	3.4	4.7	7.8	2.4	non-social	filler	Things
neutral	vase	211	2.9	6	8.1	2.3	non-social	filler	Things
neutral	vegetables	212	3.7	6.1	8.3	4.6	non-social	filler	Things
neutral	nuts	213	2.9	5.5	7	3.2	non-social	filler	Things
neutral	wires	214	2.4	4.9	5.1	4	non-social	filler	Things
neutral	wreath	215	4	5.8	7.1	3.8	non-social	filler	Things
neutral	weed	216	2.8	6.1	7.2	4.4	non-social	filler	OpenSource
neutral	baseball ball	217	3	5.9	7.9	2.7	non-social	filler	Things
neutral	bear	218	3	5	8.1	3	non-social	filler	Things
neutral	birdbath	219	2.9	5.4	5.4	5.4	non-social	filler	Things
neutral	box	220	2.1	4.9	6.3	3.2	non-social	filler	Things
neutral	camper	221	3.1	5.9	8.3	2.9	non-social	filler	Things
neutral	sidewalk	222	2.7	5.1	8.1	4.2	non-social	filler	OASIS
neutral	window	223	2.3	5.9	7.5	3.6	non-social	filler	Things
neutral	anvil	224	2.1	4.9	5.8	2.8	non-social	filler	Things
neutral	banjo	225	3.6	5.3	5.1	4.8	non-social	filler	Things
neutral	bamboos	226	2.4	5.7	8.1	3.7	non-social	filler	Things
neutral	weed	227	2.2	5.7	7.6	3.8	non-social	filler	Things
neutral	keg	228	2.1	5.4	6.2	4.2	non-social	filler	Things
neutral	ivy	229	2.3	5.3	7.5	2.9	non-social	filler	Things
neutral	yarn	230	1.5	5.1	7.7	2.7	non-social	filler	OASIS
neutral	potpourri	231	2.8	5.1	3.5	5.8	non-social	filler	Things
neutral	avocado	232	1.8	5.7	8.5	2.2	non-social	filler	Things
neutral	axe	233	2.7	4.8	7.9	2.5	non-social	filler	Things
neutral	barrel	234	2.9	5	7.5	3.3	non-social	filler	Things
neutral	bee	235	3.5	6	7.9	3.8	non-social	filler	Things
neutral	bike	236	3.4	5.1	8	2.1	non-social	filler	Things
neutral	binocular	237	3.2	5.8	7.8	2.5	non-social	filler	Things
neutral	Brussels sprouts	238	2.4	6.1	7.9	3.7	non-social	filler	Things
neutral	bulldozer	239	2	4.5	6.8	3.8	non-social	filler	Things
neutral	bus	240	2.6	5.1	7.6	3.4	non-social	filler	Things
neutral	cleat	241	2.3	5.1	6.7	3.7	non-social	filler	Things
neutral	charcoals	242	3.5	4.5	3.1	5.7	non-social	filler	Things
neutral	coasters	243	2.5	4.8	5.5	5.4	non-social	filler	Things
neutral	dartboard	244	3.1	5.2	7.6	3.6	non-social	filler	Things
neutral	parked cars	245	3.1	5.3	7.9	4.9	non-social	filler	OpenSource
neutral	grain	246	1.9	5.2	6.5	5.4	non-social	filler	Things
neutral	grape trees	247	2.5	5.8	8.1	3.9	non-social	filler	Things
neutral	green beans	248	2	5.6	6.6	4.6	non-social	filler	Things
neutral	jackets	249	2.5	5.1	7.4	4.5	non-social	filler	Things
neutral	nails	250	1.8	5.1	7.1	4.5	non-social	filler	Things
neutral	oil	251	2.6	5.7	4.6	4.3	non-social	filler	Things
neutral	palette	252	2.9	5.7	4.6	5.2	non-social	filler	Things
neutral	patch	253	2	4.5	4.4	3.2	non-social	filler	Things
neutral	payphone	254	2	4.9	3.6	5.4	non-social	filler	Things
neutral	rhino	255	3.1	5.5	7.8	3.2	non-social	filler	Things
neutral	rubber bands	256	3	5.5	6.3	4.6	non-social	filler	Things
neutral	parking area	257	3.7	4.6	7.5	6	non-social	filler	OpenSource
neutral	snowplow	258	3.5	5.7	7.5	3.6	non-social	filler	Things
neutral	steering wheel	259	4.5	6.1	7.5	3.6	non-social	filler	Things
neutral	train	260	2.4	5.1	7.6	3.1	non-social	filler	Things
neutral	sweet potatoes	261	2.8	4.8	6.8	4	non-social	filler	Things
neutral	tack	262	2.3	5.5	6.5	6.5	non-social	filler	Things