Doctoral School of Psychology of the University of Pécs

Evolutionary and Cognitive Psychology Doctoral Program

Spatial Perception and Inhibition of Emotional vs. Visual Cues of Threatening Stimuli

Doctoral (PhD) dissertation

Diána Tünde Pakai-Stecina

Consultant:

Dr. András Norbert Zsidó, PhD

2024

Pécs

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

During my academic journey, I have been fortunate to receive invaluable support from numerous individuals, and their contributions have played an important role in the completion of this work.

Foremost, I would like to thank my consultant and mentor, Dr. András Norbert Zsidó, who sparked interest for research and this particular topic in me, for his guidance and constructive criticism presented in the most perfectly rationed compliment sandwiches. I appreciate his enthusiasm, helpfulness, and patience with me.

I am grateful for the dedicated teachers and colleagues at the Psychology Institute of the University of Pécs. The wealth of theoretical and practical knowledge I gained from them laid the foundation of this work.

Special thanks go to the members of the Visual Cognition and Emotion Lab, especially to my fellow Ph.D. students Cintia Bali, Julia Basler, and Botond László Kiss, for their collaboration and assistance. I am also grateful for our research partner from New Mexico State University, Michael C. Hout, for his cooperation and his valuable insights in our research.

I appreciate the opportunities provided by the New National Excellence Program of the Ministry of Innovation and Technology. I would also like to extend appreciation to Erasmus+ and the German Academic Exchange Service for providing me with the possibility of conducting research in Germany. The support I received from the research group led by Dr. habil. Christina Bermeitinger at the University of Hildesheim was integral to the success of my work. Herzlichen Dank!

I would also like to extend my heartfelt thanks for the editorial and proofreading assistance provided by Matthew McKinney.

Finally, I am deeply grateful to my husband for his unwavering support and encouragement throughout this adventure.

ABSTRACT

Numerous studies have consistently demonstrated that attention is rapidly drawn to threatening stimuli. A longstanding debate in the field revolves around whether the root cause of this bias is primarily attributable to the affective aspects (e.g., Fear Module Theory) or the general features (e.g., General Feature Detection Theory) of said stimuli. Additionally, there is an ongoing debate (Attention Capture Debate) that revolves around the mechanisms by which salient stimuli seize our attention. On one side, theories suggest that salient stimuli will always capture attention automatically (stimulus-driven attention), while on the other hand, some suggest that these stimuli can be ignored when irrelevant to our goals (goal-driven attention). According to research in this topic, there are many factors that may influence the interaction between goal-driven or stimulus-driven processes, such as physical features of the salient object (e.g. colour, shape), or the presentation time and – place of the object. Additionally, the Signal Suppression Hypothesis suggests that it is possible to suppress the processing of visually salient stimuli before attentional capture happens.

Ensuring a robust foundation for our research, we conducted a systematic review on the topic of the perception and inhibition of salient stimuli. Then, throughout a series of three experiments that employ a combination of visual search and vigilance tasks, we led investigations, grounded in the collection of behavioural measures, encompassing response times and accuracy, coupled with insights derived from eye-tracking technology. Furthermore, it is important to emphasise that our choice of healthy young adult participants is intentional, as our research primarily focuses on examining the fundamental mechanisms of attention.

The main finding of the dissertation is that negative stimuli, when presented as distractors, are exceptionally challenging to inhibit. In the far condition task performance exhibited a noticeable decline when threatening distractors were presented, compared to nonthreatening or neutral distractors. Surprisingly, we observed that the presentation of threatening stimuli could lead to improved task performance when appearing close to the task, with no significant difference

between nonthreatening or neutral stimuli and threatening stimuli. This enhancement in performance may be attributed to the arousal stimulation effect.

1. GENERAL INTRODUCTION

The primary focus of this dissertation centres around the interaction between stimulus- and goal-directed attention when it comes to the processing of emotionally salient stimuli, particularly threatening stimuli. This research delves into the dynamics of attentional inhibition, specifically concerning the presence of threatening cues, and examines the effects of these stimuli on attentional performance.

The debate surrounding the interplay of bottom-up and top-down processes in attentional selection continues to perplex researchers, with conflicting results characterising the past decades of research (Desdimone & Duncan, 1995; Egeth & Yantis, 1997; van Zoest et al., 2004; Theeuwes, 2010; Gaspelin & Luck, 2017; Luck et al., 2021). While visually salient stimuli undeniably wield a substantial influence over attentional processes, their significance is challenged by theories emphasising top-down control (Luck et al., 2021). These studies, however, predominantly focus on physically salient stimuli. There is also a substantial body of research that delves into the influence of emotional saliency on attention (Csathó et al., 2008; March et al., 2017; Williams et al., 2006; Zinchenko et al., 2017; Zsido, Bali, et al., 2022). This line of research investigates how emotionally significant stimuli can impact attentional processes.

Evolutionary heritage has left an imprint on our visual perception, leaving it with a strong sensitivity to threatening stimuli. This heritage resulted in the rapid detection of potentially hazardous objects in our environment. A wide variety of research supports this notion (Coelho et al., 2019; Mineka & Öhman, 2002; Öhman & Mineka, 2001; Öhman & Soares, 1998; Williams et al., 2006; Zsidó et al., 2017). Numerous studies have consistently demonstrated that reaction times are significantly faster when individuals are tasked with locating threatening target stimuli as opposed to neutral ones (Becker et al., 2011; Blanchette, 2006; Coelho et al., 2019; LoBue, 2010; Subra et al., 2017; Williams et al., 2006; Zsido et al., 2017, 2019). Furthermore, it is evident that objects with emotional valence, whether positive or neutral, do not command the same degree of salience as negative stimuli (Williams et al., 2006; Charash, McKay & Dipaolo, 2006, Csathó et al., 2008;

Carretié, et al., 2011; Chapman et al., 2013; March et al., 2017; Van Hooff, 2013; Fink-Lamotte, 2022).

The advantages that threatening stimuli hold over other visually salient or affective stimuli in visual processing remains a subject of ongoing debate. It is not agreed on whether these advantages are primarily driven by visual or affective features. According to the general feature detection theory (Davey, 1995; Coelho & Purkis, 2009), threatening stimuli are deemed salient due to their specific visual characteristics, such as their distinctive shapes, skin texture, and movement properties. Visual search studies support this notion by revealing that curvilinear shapes, similar to the body of a snake, are detected more rapidly than straight or zigzag lines (LoBue et al., 2014; Van Strien et al., 2016; Wolfe et al., 1992). Conversely, the fear module theory (Mineka & Öhman, 2002; Öhman & Mineka, 2001) posits that threatening objects' salience is primarily rooted in their affective attributes.

By manipulating the distance of threatening stimuli from the centre of focus/task, we can explore the impact of visual and emotional features of their visual processing. The rapid and automatic detection of threats is facilitated by the brainstem-amygdala-cortex pathway (Liddell et al., 2005), ensuring effortless assessment and quick orientation towards threats, whether within or outside our focal attention. Stimuli appearing beyond this central area lose detail, complicating identification. To compensate for this loss, spatial attention collaborates with various eye movements to centre crucial objects in the visual field. Nevertheless, certain stimuli with elevated arousal and valence levels possess the ability to capture attention without necessitating corresponding eye movements (Calvo et al., 2008). In terms of behaviour, this implies that humans can discern emotionally significant stimuli even in their peripheral vision, despite the limited details of the stimuli (Rigoulot et al., 2012). To compare the general feature detection and fear module theories, experiments can be designed where threatening stimuli and neutral stimuli with shapes resembling the threatening ones are presented both in the fovea and peripheral vision. If the neutral stimuli provoke responses similar to the threatening stimuli in terms of attention modulation, it indicates that shape alone can influence attention and that stimuli don't necessarily have to be threatening in terms of arousal.

Taken together, this dissertation melds two key debates within the realm of attention research. The first debate regards the complex dynamics of attentional capture, particularly the interaction between stimulus- and goal-driven attentional processes. The second debate focuses on the underlying factors that make threatening stimuli salient: affective vs. physical features. In our research, we examine whether it is possible to inhibit the processing of emotionally salient negative (threatening and disgusting) information through goal-directed attentional processes. Moreover, we aim to distinguish whether the defining factor in the attentional bias towards threatening stimuli lies in their visual attributes, such as shape, or their affective qualities.

The dissertation's motivation is rooted in an extensive review of the existing literature, and it is driven by the following key objectives:

1. Addressing a gap in existing literature: Through reviewing the extensive body of research on attentional mechanisms concerning threatening stimuli, we identified a significant gap. Previous literature lacked comprehensive evidence regarding the inhibition of these stimuli.
2. Investigating the inhibition of negative stimuli: In response to this gap, our primary aim is to assess the level of difficulty of inhibiting the processing of negative stimuli when they function as distractors in a task.
3. Analysing the influence of emotional vs. physical factors in the bias towards threatening stimuli: Another goal of our research was to test whether affective or physical features are more dominant in the attentional bias towards threatening stimuli.
4. Analysing the influence of distance and position of negative distractors on task performance: Lastly, we are keen to explore how the distance from the task (close or far) of the salient objects impacts the inhibition of these stimuli.

Table 1.1 – Overview of experiments presented in the dissertation.

Study nr.	Experiment nr.	Paradigm	Short description
Study I.	Systematic review	Literature review	Investigating the inhibition of visually salient stimuli
	Narrative review	Literature review	Investigating the inhibition of emotionally salient stimuli
Study II.	Experiment 1	Visual search task	Comparing the effect of threatening and nonthreatening but visually salient distractors in close and far proximities of the target
	Experiment 2		Addition of eye-tracking data
Study III.	Experiment 1	Visual search task	Comparing the effect of disgusting and neutral distractors in close and far proximities of the target
Study IV.	Experiment 1	Semantic vigilance task	Comparing the effect of threatening and nonthreatening but visually similar distractors in close, middle, and far proximities of the task
	Replication of Experiment 1		

2. INTRODUCTION ON VISUALLY SALIENT STIMULI – A SYSTEMATIC REVIEW [1]

In our everyday lives, incoming visual information plays a very important role in how we shape our behaviour. We pick the red, ripe apple from the tree instead of the green one, we avoid the ball in a game of dodgeball, or look for our loved one's tufted hat in the crowd at the train station. However, we also often find that we are attracted by (salient) objects that we do not intentionally turn our attention to. We notice the visibility vest of a cyclist, the flashing advertisement in a shop window, the snake on the forest path, or an angry face in the crowd. Whereas in the former examples we turn towards (or away from) the stimulus ourselves through goal-directed attentional processes, in the latter cases automatic involuntary orientation is the result of stimulus-directed attentional processes.

The salience of stimuli has long been a topic of research. In visual search, the degree to which target stimuli differ from the surrounding distractor stimuli is important (Duncan & Humphreys, 1989; Moraglia, 1989; Nothdurft, 1993a, 1993b; Wolfe and Horowitz, 2017). This can be influenced by a number of visual properties, such as different contrast and luminance, colour, motion, orientation, or depth. Searching for a target stimulus that is not salient will be slower; and, the more distractors surround the target, the slower observers are to detect it (Nothdurft, 1993a, 2002). In contrast, a salient target stimulus can be detected quickly regardless of how many distracting stimuli are presented around it. To sum up, the salience of stimuli is their ability to drive attentional orientation. These properties can determine the processing order and structuring of incoming visual information (Schubö, 2009). According to Desimone and Duncan's (1995) biased competition model, simultaneously presented stimuli in the visual space compete for attentional

---

[1] This chapter is based on the following article:
Pakai-Stecina, D. T.; Zsidó, A. N. (2023). A vizuális tulajdonságok mentén kiugró ingerek hatása az inger- és célvezérelt figyelmi folyamatokra: szisztematikus áttekintés, *Magyar pszichológiai Szemle,* 78(3), 375–407.
Author contribution: **DTPS**: Conceptualization, Methodology, Data curation, Visualization, Formal analysis, Project administration, Funding acquisition, Writing – Original draft, Reviewing and Editing; **ANZS**: Conceptualization, Methodology, Supervision, Funding acquisition, Writing – Original draft, Reviewing and Editing.

processing. For example, the simultaneous presentation of two stimuli activates relevant neural representations in the visual cortex. When two stimuli activate neurons in the same part of the visual cortex, the competition for attentional processing is more intense. However, certain feedback biases may influence the position of one or the other stimulus in this competition. Such biases may be, for example, if one stimulus is unknown or salient (processing is biased towards stimulus-directed processes), or if the stimulus has greater relevance in the situation (processing is biased towards goal-directed processes). The observer's response is determined by which stimulus wins the race.

Attentional control mechanisms have traditionally been classified into two different classes: stimulus-directed and goal-directed mechanisms. These terms have been questioned in recent years, however, because their meaning and the phenomena to which they refer are unclear. In particular, goal-directed attention has been the subject of controversy. Some argue that it only describes processes that are volitional and voluntarily directed by the observer (Theeuwes, 2018). However, other definitions argue that goal-directed attentional processes describe all processes beyond voluntary actions as well, in which context, learning, or expectations may play a role. In this case, these mechanisms indirectly and automatically modulate attention (Gaspelin & Luck, 2018). Even among the authors of the studies discussed in our paper, there is no complete agreement on what exactly goal-directedness covers, and the concept is approached from several angles. In our understanding, goal-directed attentional mechanisms mean all processes that *require cognitive effort* (e.g., attentional inhibition), while we refer to stimulus-directed attention when we describe automatic processes *without cognitive effort*, triggered by salient stimuli.

It is also important to note that in this work we discuss the results of laboratory tests that do not necessarily simulate real-life situations (like those mentioned above). The examples of realistic events are intended to help understand the context of our research. Standard laboratory tasks are not realistic, but they are not necessarily intended to model reality. In general, as in the studies included in the present review, subjects find themselves in very extreme attentional situations: they are presented with a large amount of stimuli at high repetition rates to which they have to respond somehow. Thus, these studies test the limits and failures of the information-processing system, these tasks examine perceptual and attentional processes in isolation, and the results can help us to understand the general laws of psychological processes. Since we rarely face similar challenges in real life, the relevance of our research is also more specific. The results of these studies may be useful in measuring how people can function in situations where attentional-cognitive abilities are used to an extreme (e.g. air traffic controllers, airport security controllers, pilots, power plant operators, surgeons, etc.).

The aim of our review article is to collect and organise standard laboratory studies on the operation of stimulus-directed and target-directed monitoring processes since the early 2000s. We focus on the last two decades or so because the earlier studies and their results have been previously summarised (Simons, 2000; Pashler, Johnston, & Ruthruff, 2001; Ruz & Lupiáñez, 2002), and we wanted to focus on the most recent results. In the present review, our primary aim is to demonstrate the effects of stimuli that are salient along their visual properties on stimulus-directed and goal-directed attentional processes, shedding light on the controversial question of whether goal-directed attentional control can emerge in the presence of these stimuli. In our review, we refer to the results of eye movement studies and the neural correlates of attentional selection (ERP – event-related potential studies), and the results of studies testing movement linked to response-execution. As the focus of this paper is on visual attentional processes, we do not discuss the results of auditory processing and of stimuli that are salient along emotional properties. These are all similarly important studies that are worthy of a similar summary in their own right. Since they may differ in several points, both theoretically and in terms of processing, from studies dealing with visual salience alone, we have opted for a narrower focus due to coherence constraints.

2.1 Stimulus-Directed Attentional Processes

When attention is divided in the visual space, attentional capture is not conscious and happens automatically (Theeuwes, 1991, 1992). That is, the preattentive processes prior to attentional processing are directed exclusively by the characteristics of the stimuli in the visual field (Neisser, 1967). After the preattentive analysis of the visual field, the object that captures attention (i.e., the singleton) is selected for further analysis. Identification of the selected object is only possible after its analysis; during the preattentive processes, only the position of the object and differences in local properties (e.g., colour, contrast, orientation) can be detected. In a visual search situation, if the object matches the target that the observer is looking for, the observer will respond. Distractor stimuli in the environment can be salient, while the target stimulus does not necessarily have salient properties (Theeuwes, 2010). Attention is directed towards visually salient stimuli, which in many cases is reflected in the saccade to the stimulus (Theeuwes, 1998). In experiments investigating this phenomenon (e.g., Theeuwes, 1991; 1992), subjects were usually required to look for an easily detectable target among distracting stimuli; for example, a diamond shape among circles. The stimuli were presented around a fixation point, within a search field usually consisting of six to eight stimuli. In the middle of each stimulus was a horizontal or vertical line, the direction of which was used to indicate whether the subject had found the target. When one of the distractor stimuli differed in colour or shape from the others (thus becoming salient), the reaction time to detect the target increased (Egeth & Yantis, 1997; Theeuwes, 1991, 1992). Thus, if the distractor stimulus is salient in some of its visual features in the visual field, performance on the task would be impaired due to the interference this salience causes (Theeuwes, 1992, 2010).

2.2 Goal-Directed Attentional Processes

Goal-directed attention is a volitional process whereby we consciously prefer (or even inhibit the processing of) a stimulus, place, or feature that is relevant, or notably irrelevant, to us and our current goals. In this way, neural activity is enhanced towards relevant stimuli, while neural responses are inhibited towards irrelevant stimuli (Desdimone & Duncan, 1995; Katsuki & Constantinidis, 2013). Neural responses can be well described by psychophysiological indicators of event-related potential (ERP). A good indicator of attentional selection is the N2pc component (contralateral posterior negative potential between 200-300ms after stimulus presentation), regarding which two theories are important to note.

According to the attentional allocation hypothesis, this component indicates attention to the stimulus (Luck & Hillyard, 1990), whereas according to the attentional selection hypothesis, the greater the effort required to inhibit the surrounding distracting stimuli, the greater the amplitude of this component will be (Luck & Hillyard, 1994; Czigler et al, 2006; Czigler, Sulykos, & Kecskés-Kovács, 2014). Another good indicator is the Pd component (distractor positivity; a contralateral lateral-occipital positive wave between 300 and 350ms after stimulus presentation), which is an electrophysiological sign of attentional inhibition and can be observed when distracting stimuli are presented (Hickey, Di Lollo, & McDonald, 2009; Sawaki & Luck, 2010).

Goal-directed inhibition is possible in the presence of semantic and contextual information. For example, during attentional control, our expectations about the appropriate or habitual location of objects play an important role in the execution of eye movements while scanning the visual field. For instance, if we are looking for an electrical socket in a room, we are likely to start by looking at the lower half of the walls, rather than the ceiling area (Hwang, Higgins, & Pomplun, 2009).

2.3 Signal Suppression Hypothesis

According to the signal suppression hypothesis, although visually salient distractors generate a "look-at-me" signal, this signal can be actively inhibited by goal-directed control before they capture attention (Sawaki & Luck, 2010). The theory is based on an ERP study in which participants searched for a letter on a split screen. During the task, capital letters in different font-sizes (smaller and larger) were presented, within which a specific letter of a specified font size was targeted. Participants were instructed to always look at only one area of the screen (top or bottom) and to detect the target on that side. The other half of the screen was to be ignored. Salient distractors were matched in identity to the target (i.e. if the target was the large A, the similar distractor was the small A). In the control condition all stimuli were either red or green, while in the test trials a different/salient coloured distractor was also included (i.e., a green letter between red stimuli, or vice versa).

The target and all distractors could appear in the attended or unattended area. Irrelevant salient stimuli did not produce a signal for attentional capture (based on the N2pc component, conducted at electrodes PO7 and PO8, at amplitude averages between 115 and 225 msec), but induced attentional inhibition (Pd component, conducted at electrodes PO7 and PO8, at amplitude averages between 225 and 300 msec) on both the actively and inactively observed sides of the split screen. Later, in an eye-tracking study (Gaspelin, Leonard, & Luck, 2017), subjects were asked to indicate the direction of a line. The lines were presented within heterogeneous shapes (similar to those in studies by Theeuwes 1991; 1992), and the distractor stimuli included a salient stimulus of a different colour. Because it was important in the task that the target would not become salient, the target stimulus was always the same shape (e.g., square) among a variety of other shapes (e.g., circle, triangle, diamond). Thus, instead of a singleton search strategy, subjects used a feature selection strategy (always searching for the square). According to the results, initial fixations were directed less often to the coloured distractor than to the non-distractor; indicating that participants successfully inhibited the "look-at-me" cue before they even looked at the stimulus (Gaspelin, Leonard, & Luck, 2017). Thus, attentional control can be established according to current goals through goal-driven cognitive processes (Luck et al, 2021; Sawaki & Luck, 2010).

2.4 Attention Capture Debate

To date, there is no consensus on whether goal-driven processes or stimulus-driven mechanisms dominate attentional selection (Desdimone & Duncan, 1995; Egeth & Yantis, 1997; van Zoest et al., 2004; Theeuwes, 2010; Gaspelin & Luck, 2017; Luck et al, 2021). According to the theory of contingent involuntary orienting, a salient stimulus attracts attention only if it corresponds to the attentional set in the current situation (Folk, Remington, & Johnston, 1992). This set is shaped by the explicit or implicit goals of the observer. In everyday life, the goal may be expressed in action plans such as "find the keys", but it may also be the result of a researcher's instruction given to a participant (Egeth & Yantis, 1997). For example, if a red circle is to be detected in a task, the attentional set encouraged by the task includes any stimulus that might be the target stimulus – including an irrelevant, saliently coloured distractor stimulus if it matches the shape of the target stimulus (Luck et al, 2021). Conversely, no matter how salient a stimulus is, if it is not part of the attentional set in the given circumstances, it is not capable of distracting us (Gaspelin, Leonard, & Luck, 2017). This is illustrated by a classic study (Hillstrom & Yantis, 1994) in which the target stimulus was a rotated letter T that had to be located among rotated Ls scattered on the screen. During each trial, one stimulus moved – this could be the target stimulus or one of the distractors. Since movement is a salient feature, the expected result was that subjects would have faster reaction times for moving target stimuli compared to non-moving ones. In contrast, the moving target did not provide an advantage in task performance, and reaction times did not differ between the two conditions because participants' attention set included letters and not movement. However, these studies do not answer the question of whether attentional orienting to salient stimuli outside the attentional set does not occur at all, or if it does occur but is immediately overridden by attentional control (Luck et al., 2021).

2.5 Guided Search

According to the Feature Integration Theory of Treisman and Gelade (1980), in the first stage of visual processing we automatically gather information about basic visual features such as colour, shape, size, and movement. All features are processed together (in parallel) without focused attention or voluntary effort. Each feature is processed by special modules that form feature maps (i.e., showing where in the visual field the feature is located). The integration of features (i.e., the combination of several features), leads to object recognition. This can be achieved in three ways: (1) based on prior knowledge, (2) using the so-called "master map", where the location of all features is shown and through focused attention, we are able to recognise the object by combining the features that are active at the time using our prior knowledge, or (3) by automatically combining individual features, which can lead to misperceptions (illusions). When a process requires complex integration, we first detect each of the discriminative features and then combine them. In this case, the processing is not parallel (but sequential) and therefore requires attentional effort. In Treisman and Gelade's (1980) study, subjects had to find the green letter ‘T’ among green ‘X’s and brown Ts. The more distractor stimuli were presented around the target, the slower the participants found it. However, when the target had a unique feature (e.g., blue letter S – colour and shape were unique), processing was parallel, and the number of distractors did not affect the speed of the search. In the first case, the features are detected separately by the corresponding modules, which then appear in the master map, and focused attention is directed to them. Thus, it is a slow process, as on average at least half of the possible locations in the search field have to be looked at. In the second case, however, the individual (salient) features will attract attention, only a single location will be active in the master map, and the process will be fast (Treisman & Gelade, 1980; Zsidó, 2022).

The Guided Search Theory proposed by Jeremy Wolfe is a model of visual search that does not favour stimulus-driven or goal-driven processes but rather argues that an adaptive processing sequence prevails during visual search (Wolfe, 2021). According to the theory, preattentive information forms a spatial priority map which includes the following components: stimulus-driven attributes, goal-driven knowledge, previous experiences and events (e.g., priming and cueing), reward, and syntax/semantics of the situation. Of these, selective attention favours the most active area, depending on the situation. In addition, an important biasing factor is the non-uniformity of search in the visual field, with stimuli that are closer to fixation being preferred. In addition, three Functional Visual Fields (FVF) mediate spatial attention: (1) the resolution of FVF varies with the number of stimuli presented, (2) the FVF that controls voluntary/searching eye movements constrains overt eye movements in the search field while the target stimulus is being searched, (3) the FVF that controls attentional processes controls the voluntary decision to leave the current fixation and select the next stimulus to attend to. Finally, the template of the target is stored in memory, and the search for the target involves the processing of multiple stimuli simultaneously and asynchronously (Wolfe, 2000, 2021). In summary, attentional orientation in the visual field is a multifactorial process that cannot be interpreted along the lines of stimulus-driven and target-driven mechanisms alone.

2.6 Aim of this Review

The aim of our review is to analyse the results of relevant research on stimulus-driven and goal-driven visual attention processes starting from the early 2000s. We aim to explore the interaction of stimulus-driven and goal-driven attentional mechanisms during attentional selection. Furthermore, we aim to investigate, using behavioural and psychophysiological data from a healthy adult population, the task or stimulus characteristics and factors that favour one or the other mechanism during attentional selection.

2.7 Method

Our study was conducted using the APA PsycNet search engine (query date: 1 December, 2022), filtered for articles published in the year 2000 or later, using the following keywords: attentional capture debate, stimulus-driven and goal-driven attention, salience, and attentional inhibition. We selected studies in which all keywords were present. The articles returned were first filtered by title and then by abstract. The full text of the articles, selected by abstract, was reviewed. The results reported by the studies were summarised in a table (see Table 1). To be considered, studies must have: (1) been scientific (peer-reviewed) journal articles, (2) been empirical studies (no reviews or meta-analyses), (3) had young adult (18-30 years old) human samples, (4) had nonclinical samples, (5) reported behavioural and/or psychophysiological data describing stimulus-driven and goal-driven attentional processes. Only English-language articles were included in the analysis. The checklist of Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA 2020) were considered (Page et al., 2021).

2.8 Results

The search resulted in a total of 201 articles, of which 14 were selected for our systematic review. A total of 33 studies were included in the 14 articles. The results of the articles included in our review are presented in Table 2.1 (presented in Supplementary Material 1). The studies featured in our review included the following main task types: cueing paradigm, visual search task, Rapid Serial Visual Presentation (RSVP) task (Forster, 1970), and observation of eye movements (free viewing).

2.8.1 The Effect of (Salient) Visual Features on Attentional Capture

In our review, we found a number of articles that attribute great importance to the visual properties of distracting stimuli in attentional mechanisms. In most cases, distractors of the same colour as the target stimulus resulted in significant stimulus-driven attentional capture. In a cueing study by Carmel and Lamy (2015) (see Figure 2.1), attentional capture was only observed due to a cue of a different colour than the target stimulus when it had a presentation time of 150ms. With a shorter presentation time of 50ms, the different-colour stimulus was successfully inhibited by the subjects. However, when the colour of the cue was the same as that of the target, there was a significant stimulus-driven effect on task performance even with a presentation time of 50ms.

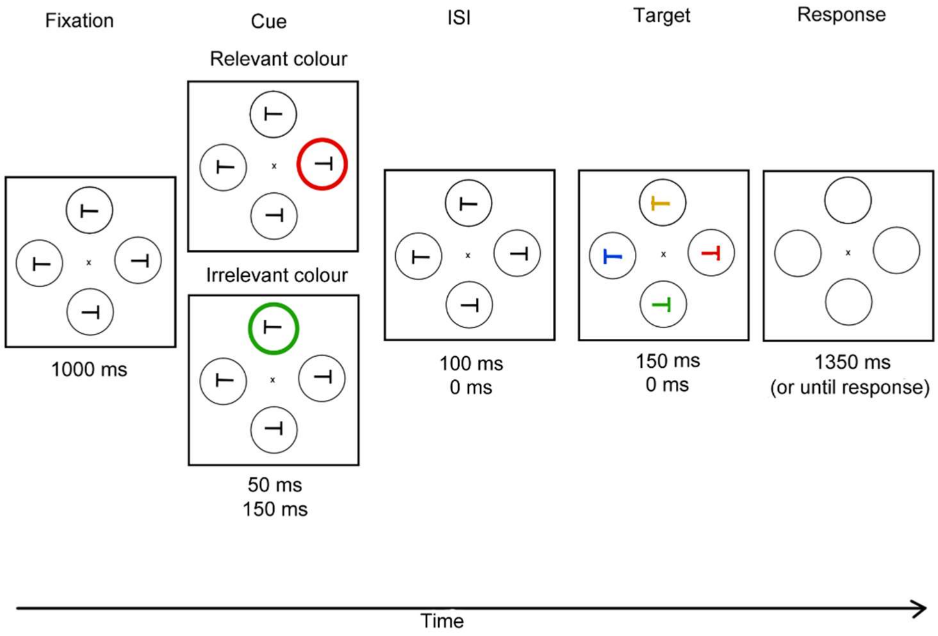

Figure 2.1 – Cueing paradigm used in the study of Carmel and Lamy (2015). In such paradigms, the cue is presented before the search field. Depending on the task type, the cue can either predict the position of the target (congruent position) or

deviate from it (incongruent position) to a given extent. In the task shown in the picture, the target stimulus was the red-letter T and the participant had to indicate the direction of the target (tilted to the right or left). The other tests in our review that use a cueing paradigm operate on a very similar principle, regardless of the difference in the stimulus material and response mode.

Dieciuc, Roque, and Boot (2019) also used cue stimuli that modified the cursor trajectory during task performance, especially when the cue stimulus colour was the same as the colour of the target. The cue stimulus also captured attention and diverted the cursor trajectory when it did not resemble the target, however, in such a case, the effect was not as strong.

Mast and Frings (2014) also found that a cue stimulus with the same colour as the target stimulus generated a strong stimulus-driven effect, and later found that the more similar the cue and target are (colour, shape, location), the stronger this effect is. This was also true when the cue was masked, reducing its visibility.

Similar results were obtained in the study of Lamy, Leber, and Egeth (2004). In the task, the target was presented at six possible locations, preceded by a cue that was of (1) the same or (2) partially the same colour as the target, or it had (3) a different but also prominent colour. If the colour of the distractor cue was the same as the target's or it contained the same colour as the target, performance on the task was impaired. However, successful inhibition was observed for cue stimuli of a different salient colour.

The phenomenon was further investigated in an RSVP task (Lamy, Leber, & Egeth, 2004), where participants were asked to detect a red or green target letter among successively presented letters of different colours. Eight '#' characters around one of the presented distractor letters, which either matched or differed from the colour of the target stimulus, were used as the distractor stimuli. The task was further divided into two conditions: in the homogeneous condition, all '#'s were of the same colour, while in the heterogeneous condition, the distractors were of different colours. In the latter condition, attentional capture was only observed when the colour of the target appeared among the colours of the distractors, or when the cue appeared two to five stimuli before the target. In the homogeneous condition, cue stimuli of the same colour presented just one stimulus before the target significantly impaired performance. Cue stimuli that differed in colour from the target stimulus showed no stimulus-driven effects on attentional mechanisms.

The strong attention-modulating effect of visual properties can also be observed in Schubö's (2009) visual search task (see Figure 2.2). Eight shapes were placed around a fixation cross, one of which was the target stimulus, while the others were distractors. The task was divided into two conditions. In the target-only condition, only the target was salient – it was either a different colour or shape than the other stimuli (e.g., a red circle among green circles or a green diamond among green circles). In the target-distractor condition, in addition to the salient target, a salient distractor stimulus was also included in the search field. Participants had significantly worse performance when the task included a salient distractor stimulus, and this effect was significantly greater for colour than for shape. Thus, colour had a stronger stimulus-driven effect on attention than shape. In addition to behavioural data, ERP was also measured. The N1 (140-170ms latency) and N2 (210-270ms latency, both conducted at PO2 and PO3 electrodes) components indicating attentional capture showed that in the target-only condition, spatial attentional selection towards the target was easier, whereas in the target-distractor condition, attention was more divided, and inhibition of the salient distractor was more difficult. The N2pc component, which indicated attention to the target stimulus, did not differ between the two conditions when a stimulus of a different colour was to be searched for. When the differently shaped stimulus was the target, the magnitude of the component decreased in the target-distractor condition depending on the position of the salient colour distractor, with inhibition of the salient colour distractor requiring more effort.

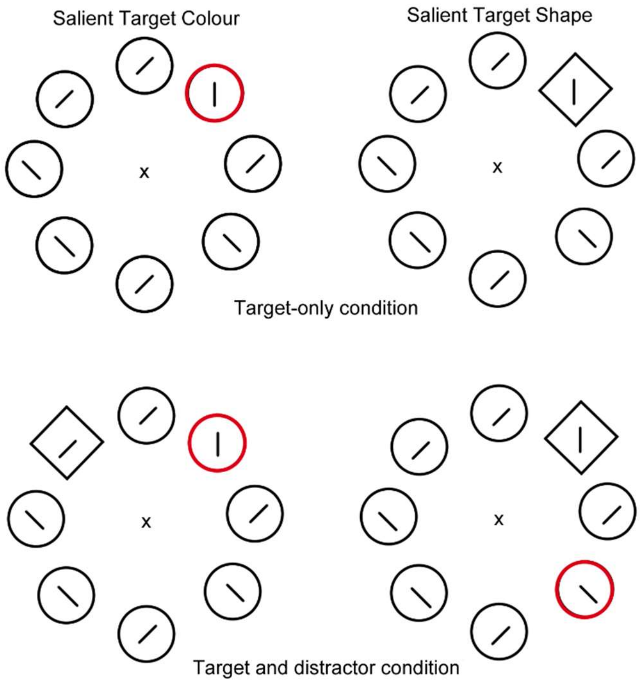

Figure 2.2 – Schubö’s (2009) visual search study. In visual search tasks, multiple stimuli are presented simultaneously in the search field, and the task of the participant is to detect the target stimulus. Above is the visual saliency of the target along different features (left: colour, right: shape) without distracting stimulus. Below, in addition to the salient target, a distractor stimulus is presented that is salient along other visual properties (e.g., left: red colour – target, diamond – distractor stimulus). Other studies referenced here which use this paradigm operate on a very similar principle, regardless of the difference in the stimulus material and response mode.

In summary, although physical properties have a large influence on the working of attentional mechanisms, it is also important when and for how long the distractor appears in the search field. In the study of Carmel and Lamy (2015), cue stimuli of a different colour from the target were only able to produce a strong stimulus-driven effect when presented for a longer duration (150ms). In the RSVP task, distractor stimuli of different colours only captured subjects' attention when presented two to five stimuli before the target stimulus (Lamy, Leber, & Egeth, 2004). However, these results are all valid in a laboratory task situation (cf. Czigler, 2022). Parkhurst et al. (2002) aimed to model everyday situations by observing natural eye movements in their eye-tracking study. Participants were asked to freely observe images (of four categories: interiors, nature, cityscape, fractals) presented. Their results showed that the first fixations, as well as subsequent saccades, were directed at salient areas of the images. They concluded that under normal viewing conditions, without a task, the salient areas have priority in attentional orientation (Parkhurst, Law, & Niebur, 2002).

2.8.2 The Effect of Presentation Time and Location of the Distractors on Target Detection

The reviewed papers also showed that the duration of presentation of the distractor stimulus and its location also have a significant effect on attentional processes. The length of time the distractor stimulus is presented and where it appears in the search field may also significantly modulate attention. For example, if the distractor is presented at the same time as the target stimulus, performance is impaired, even if the preceding cue stimulus predicts the location of the target. In the study of Schreij et al. (2014), participants searched for the target at four possible locations in the search field. The target was a red letter. In the other three locations, a white letter distractor was also presented. Prior to the search field, a cue matching the colour of the target was also presented, which predicted the location of the target in 25% of the cases. In half of the trials, not only the cue but also an extra distractor letter was presented at the same time as the target, which also resulted in slower reaction times. Performance was the worst when both distractors appeared in the same trial, i.e., when the cue did not indicate the location of the target (invalid cue) and the extra distractor was present in the search field.

However, according to Livingstone et al. (2017), it is not attentional capture that occurs in response to the cue stimulus, but rather increased processing induced by the cue being prolonged over time. Based on a previous ERP study (Sawaki & Luck, 2013), participants were asked to detect the missing side of a coloured target square among three other squares that were of different colours with missing sides. The search field was preceded by the presentation of cue stimuli. The cue stimuli consisted of four coloured circles; one of which was the same colour as the target but did not predict its location. Livingstone et al. (2017) found that a cue of the same colour as the target elicited enhanced processing (CP component = cue-evoked Pd component – contralateral positivity, between 400-450ms after cue presentation or between 100-150ms after target presentation, conducted at PO7 and PO8 electrodes), which was not limited to the presentation field of the cue but also extended to the subsequent search field. In the case where the cue stimulus was presented at the same location as the target stimulus, the processing of the target stimulus was enhanced. If the cue was not presented in the same location as the target, then the processing of the interfering stimulus/location was enhanced, creating a competition with target detection that requires a longer time to resolve.

Burnham et al. (2010) also obtained similar results. They used a static line as a cue stimulus. Before the search field appeared on the screen, a static line consisting of the letters ‘X’ and ‘O’ was used as a cue. The "break" in the line where the letters ‘X’ and ‘O’ met was the position of the cued location. The search field appeared after the cue, where the stimuli were presented in the same location as the line had been. Participants searched for the target (‘*’ or ‘&’) between special characters (e.g., ‘@’, ‘!’, ‘$’). The cue did not predict the location of the target stimulus, yet their reaction times were significantly faster when the target appeared at the location of the ‘X’-‘O’ shift of the cue line (Burnham et al., 2010).

2.8.3 Is Goal-Driven Control Possible?

According to the signal suppression hypothesis, stimulus-driven processing can be inhibited by goal-driven control (Sawaki & Luck, 2010; 2013). The theory suggests that although the salient stimulus generates a "look-at-me" signal (detectable by the N2pc component), goal-driven control can be used to inhibit the information before attentional processing (indicated by the Pd component). Although there are less results supporting this theory than demonstrating the advantage of stimulus-driven processing, these findings hold value in understanding the workings of attentional mechanisms.

Gaspelin, Leonard, and Luck (2017) came across visual search and eye-tracking results suggesting that when the singleton search strategy is not enforced during task performance, the salient distractor stimulus is inhibited. In their study, the singleton search strategy was contrasted with the feature search strategy. In the first study, the task was to find a salient target stimulus among six identical stimuli (e.g., a green diamond stimulus among five green circles) with a salient colour among the distractors (e.g., a red circle). In this case, the salient distractor had a strong effect on both oculomotor and behavioural outcomes. Participants' performance was impaired (slower reaction time) in the presence of the salient distractor and the first saccades fell significantly more often on this stimulus than on the other distractors. However, when subjects were no longer required to find a singleton (e.g., a green circle target stimulus among different shapes of green colour) and a salient colour stimulus was presented (e.g., one of the distractors was red), the stimulus-driven effect was no longer detectable. In this case, performance on the task was not impaired in the presence of the salient distractor, and the number of first saccades on the salient stimulus is significantly reduced compared to the first trial (Gaspelin, Leonard, & Luck, 2017).

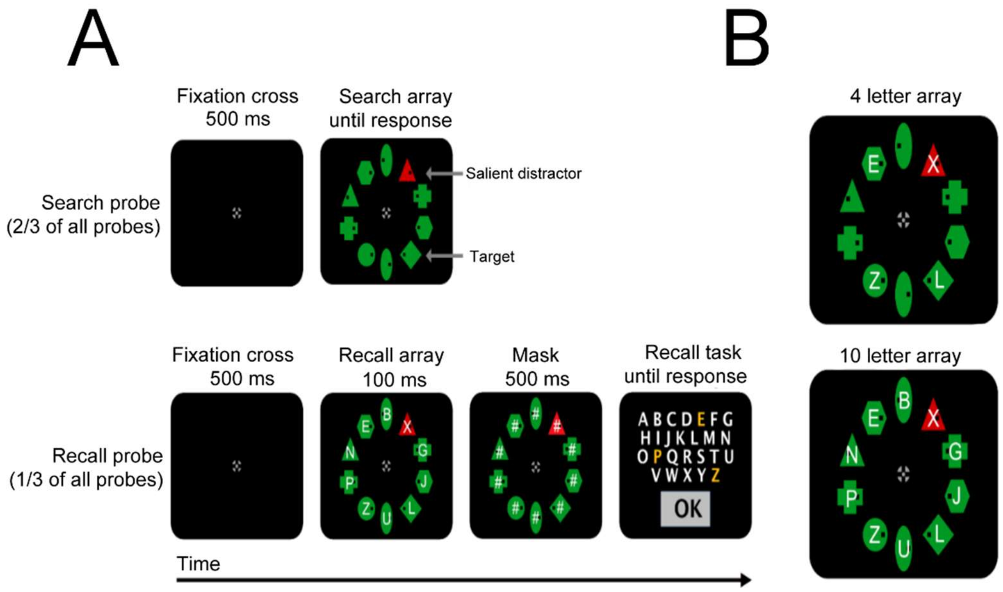

Figure 2.3 – Stilwell and Gaspelin's (2021) study, in which the visual search task was supplemented with a recognition task. The search trials were identical to the classical visual search task (searching for a target stimulus among several

distracting stimuli, see Figure 2.2). During the recognition trials, white letters appeared briefly within the stimuli, which participants were asked to memorise. The appearance of the letters was followed by a mask, and then by a task field where they had to recall the letters (A). The test used conditions with 4 and 10 letter layouts (B).

This result (Gaspelin, Leonard, & Luck, 2017) is supported by the study of Stilwell and Gaspelin (2021) (Figure 2.3), where, supporting the feature search strategy, participants had to find a shape among ten green shapes of different types (e.g., a green diamond shape among green other shapes), while one of the distractors was of a salient colour (red). In the first condition reaction time was measured. In the second condition, (4 or 10) white-coloured letters were placed in the stimuli and then they had to be recalled. Neither reaction times nor recall performance was affected by the presence of a salient distractor stimulus. An interesting finding, however, was that in the four-letter arrangement, the letter appearing in the salient stimulus was recalled significantly less often by participants than the letters appearing in the other stimuli. In the ten-letter arrangement this effect was reduced. However, the strength of this effect was problematic, which was addressed in a new study by increasing the sample size (from 24 to 40) and by changing the fully coloured shapes to coloured outlines on a grey – instead of black – background. These modifications did not fully replicate their previous results, as the salient colour distractor significantly reduced task performance. However, similarly to their previous results, the inhibition of the salient stimulus in the four-letter condition was stronger in the recognition task, suggesting the importance of the number of stimuli presented simultaneously (set-size).

This is confirmed by the study of Wang and Theeuwes (2020). In their visual search task, participants had to find a target stimulus (e.g., a green circle) among four, six, or ten green shapes of different types. They also presented a salient distractor stimulus, which was red. Goal-driven control was only observed in the four-stimulus conditions, in which case there was no deterioration in reaction times due to the salient distractor. However, in the conditions of six and ten stimuli set-sizes, there was an increasing deterioration in task performance due to the presence of the salient distractor. In the other condition of their study, letters were placed in the presented stimuli which were later recalled by the participants. When the set-size consisted of four stimuli, goal-driven control prevailed, with participants recalling significantly more letters from the non-salient stimuli. However, this difference disappeared in the six-shape condition, while in the ten-shape condition it was reversed, and the letter of the salient stimulus was recalled more often (Wang & Theeuwes, 2020).

2.9 Discussion

The studies included in our review show that several factors can influence attentional orientation in the presence of a salient stimulus. In our review, three main results were obtained: (1) the colour of the salient stimuli, (2) the presentation times of the distractor and target stimuli, and (3) the number of distractors are all important factors in the control of attentional processes.

The reviewed studies suggest that the similarity of target and distractor stimuli plays a crucial role in attentional capture (Carmel & Lamy, 2015; Dieciuc, Roque, & Boot, 2019; Lamy, Leber, & Egeth, 2004; Mast & Frings, 2014; Schubö, 2009). When the colour of the salient distractor stimulus matches the colour of the target stimulus, the salient distractor almost always elicits a strong stimulus-driven effect, whether in a cueing paradigm (Carmel & Lamy, 2015; Dieciuc, Roque, & Boot, 2019; Lamy, Leber, & Egeth, 2004; Mast & Frings, 2014) or a visual search task (Schubö, 2009). In cases where the colour of the distractor and target stimuli do not match, but the distractor stimulus is salient in its other features (e.g., shape), attentional inhibition is more likely to be observed (Lamy, Leber, & Egeth, 2004), or the stimulus-driven effect is less pronounced (Schubö, 2009). If the colour of the distractor stimulus and the target stimulus does not match, but the distractor stimulus has a different, salient colour, the stimulus-driven effect is also observed in many cases (Schreij et al, 2014; Carmel & Lamy, 2015; Dieciuc, Roque, & Boot, 2019). One may wonder why colour is a salient trait, and whether these results could be a by-product of the fact that colour and contrast are easier to manipulate than other variables in test setups. Wolfe and Horowitz (2004, 2017) have established the unquestionable primacy of four traits in attentional processing through repeated demonstrations. These are colour, motion, orientation, and size. Our results seem to support their assumption about colour. Luminance and shape also feature prominently in the analysis, both appearing as likely guiding attributes, which is also consistent with our results. Overall, it is likely that the results are not specific to colour as a trait only but are also true to other salient traits; most studies manipulate colour because it is the easiest from a methodological and technical perspective. Understanding which features are primary in processing can contribute to modelling the mental representation of visual space. Presumably, these are the clues that can help us to automatically perceive sketches in complex and rapidly changing environments (Oliva & Torralba, 2006), and thus to follow what is happening and predict what will happen around us.

The results of the reviewed studies suggest that time is also a relevant factor mediating stimulus-driven processing. A distractor stimulus appearing at the same time as the target stimulus may capture attention (Schreij et al, 2014) if the number of stimuli presented simultaneously exceeds four (Stilwell & Gaspelin, 2021; Wang & Theeuwes, 2020). For salient cueing stimuli, longer presentation times (> 150ms) can enhance the attentional capture effect (Carmel & Lamy, 2015), as can longer presentation times in an RSVP task – the distractor stimulus must be presented at least two to five stimuli before the target stimulus to elicit a stimulus-driven effect (Lamy, Leber, & Egeth, 2004). Distractor stimuli presented as a cue before the search field are subject to increased processing, which extends to the search field in time, which then results in increased processing of the stimulus in the same location (Livingstone et al, 2017). The guided search theory (Wolfe, 2021), which combines the serial-parallel nature of attentional processing, compares the processing of stimuli to a car wash. Although cars enter and exit the car wash (of limited capacity) like an assembly line, several cars are getting in and out of the car wash at the same time. The selection time is, therefore, shorter than the recognition time and, consequently, at any given moment of the search, there are several elements in the recognition process occurring at the same time. If, in addition, one of these elements attracts attention by its salient feature, the next element may take longer to be processed. The effect of a salient distractor on attentional processing is most pronounced when the attentional system is under temporal pressure and has to process several stimuli simultaneously. This can also occur in everyday life, for example when driving a car or walking (e.g., while crossing the road at an unmarked pedestrian crossing to catch an oncoming bus).

Therefore, for goal-driven control to be effective, several preconditions must be met. The first and most important factor is that the singleton selection strategy cannot prevail in the task, but rather a feature-based search should be used (Gaspelin, Leonard, & Luck, 2017), with goal-driven information being more active in the spatial priority map (Wolfe, 2021). In the study of Sawaki and Luck (2010) formulating the signal suppression theory (described in the theoretical introduction), the number of false alarms in the actively attended area increased when a distractor stimulus similar to the target stimulus but not of salient colour (same letter but different size) was present. This similar stimulus and the target stimulus were inhibited in the unobserved area, and this phenomenon was referred to as test control in the study (evidence that the observed and unobserved areas were separated). Also, according to the ERP results, N2pc (attentional capture) was elicited only by the target stimulus and the similar distractor stimulus, and only in the actively attended area; whereas Pd (inhibition) was elicited only by the salient distractor stimuli in both areas (Sawaki & Luck, 2010). Thus, inhibition may have been induced despite the salient colour, but it was not discussed that the similar stimulus within the active area became salient and that it could no longer be inhibited by the subjects. Thus, perfect target-driven control may be difficult to maintain, even when using feature search and favouring information that is relevant to our goals. This is in line with the contingent involuntary attentional orientation theory, saying that only salient stimuli that can be included in the task-stimulated attentional set are able to capture attention (Folk et al., 1992). In the study of Sawaki and Luck (2010), the colour distractor stimulus was thus less salient than the distractor stimulus that was not salient in colour but was similar in identity to the target. Nevertheless, the work of Stilwell and Gaspelin (2021) has shown that in many studies that specifically support a goal-driven theory, the efficacy of the tests can be problematic. As the sample size is increased, the inhibition effect disappears, and task performance deteriorates. Moreover, increasing the set-size also seems to eliminate the goal-driven control (Stilwell & Gaspelin, 2021; Wang and Theeuwes, 2020), which is consistent with the operation of resolution FVF of the guided search theory (Wolfe, 2021) and the limited capacity of the processing system.

Thus, based on the current findings, it is not possible to state clearly whether only stimulus-driven or only goal-driven mechanisms mediate attention, nor even whether one or the other is more prominent in attentional processes. Rather, it can be said that, depending on the situation, stimulus-driven and goal-driven processes interact, and a number of factors (e.g., colour of stimuli, time and place of presentation, number of stimuli presented) may influence which is more predominant. A distinction should also be made between the types of tasks used in the studies, as their choice may inadvertently support one theoretical framework or another. Our summary has made it clear that stimulus-driven attentional processes play a greater role in cueing and singleton search tasks. Goal-driven processes, on the other hand, are more prevalent in tasks with feature search strategy when certain conditions are met (e.g., smaller set-size).

It is also worth noting what was already mentioned in the introduction: these studies are not suitable for modelling everyday life; the results are only attempting to describe general truths about attentional processes. Of the research reviewed, only the study by Parkhurst et al. (2002) approximates a real-life situation to some extent, but even this cannot be considered a model of real viewing conditions. However, as we have seen, it is very difficult to separate attentional processes even in laboratory-controlled tasks – so it is very likely impossible in everyday situations. Nevertheless, information on the failures and limitations of the attentional system can provide us with useful practical knowledge in many areas of life. For example, in the specific jobs already mentioned, it can help with the screening and training of employees or help diagnose and treat dysfunctions of the attentional system (brain damage, attention deficit disorders).

3. INTRODUCTION ON THE SALIENCE OF THREATENING STIMULI – A NARRATIVE REVIEW

Fear, recognized as a fundamental and ancient emotion crucial for survival (Ekman & Friesen, 1971; Ekman, Sorenson, & Friesen, 1969), plays an essential role in assessing situations as safe or dangerous, guiding decisions on approach or avoidance. The concept of a "fear module" has been proposed, positing that humans possess an evolved mechanism for rapid threat detection (Öhman & Mineka, 2001). This processing is fast, automatic, and subconscious, relying on specific cues that are negative, threatening, and/or relevant for survival. The fear reaction, once evolved, remains encapsulated and resistant to conscious control, with the amygdala playing a central role in the processing of fearful cues (Coelho & Purkis, 2009; LeDoux, 2000; Pessoa & Ungerleider, 2005; Vuilleumier, Armony, Driver, & Dolan, 2001).

The basis of this theory is evidence suggesting that threat-relevant targets surrounded by threat-irrelevant distractors are detected more rapidly than threat-irrelevant targets amidst threat-relevant distractors (Soares et al., 2009, 2014; Öhman et al., 2012). Öhman and colleagues (Öhman, Flykt, & Esteves, 2001) demonstrated an attentional processing advantage for fear-relevant stimuli (spiders, snakes) compared to non-fearful stimuli (mushrooms, flowers). In a visual search task, participants were shown a matrix of pictures, and were instructed to detect the odd-one-out (a snake or spider among flowers or mushrooms and vice versa). They detected snakes and spiders more quickly among mushrooms and flowers than the reverse scenario. Based on their findings, Öhman et al. (2001) suggested that the processing of these negative stimuli is automatic, unaffected by variations in matrix size during the search task.

Supporting that notion, functional magnetic resonance imaging (fMRI) studies have proved a significant role of the amygdala in the detection of threatening stimuli (LeDoux, 1994, 2000; LeDoux, Cicchetti, Xagoraris, & Romanski, 1990). According to these studies, the amygdala can swiftly activate through the subcortical "low road" (LeDoux, 2000), utilising the right amygdala – superior colliculus – pulvinar nucleus (thalamus) pathway (Morris et al., 1999). Importantly, this pathway operates independently of the cortex, in contrast to the more consciously processing "high road." This subcortical route aids in stimulus discrimination, indirectly facilitating faster identification, involving the visual cortical areas.

Moreover, the attentional bias for threatening stimuli has been proven to be present in child populations as well. Waters, Lipp, and Spence (2004) pioneered this exploration using a dot-probe paradigm, revealing that children display a heightened attentional bias toward threatening stimuli compared to non-threatening ones. Building on this, LoBue and DeLoache (2008) adapted the classic visual search task (VST) developed by Öhman and colleagues (Öhman et al., 2001; Öhman & Mineka, 2001) to assess fear advantages in children. In the experiment, one image from a different category (threatening – neutral) serves as the target within an array of eight distractors. LoBue and DeLoache (2008) introduced a touchscreen version of the VST, demonstrating that preschool children exhibit attentional bias and a visual search advantage for snakes, even without reported snake fears. This pattern was also observed in their investigation of spiders (LoBue, 2010a). Zsidó et al. (2018) included modern threatening stimuli (e.g. syringes) as well as evolutionary ones (e.g. spiders) and revealed that children demonstrate quicker detection of threatening cues regardless of the evolutionary age of the stimuli. Interestingly, they also exhibited faster detection of non-threatening evolutionary targets compared to non-evolutionary ones. It was proposed that distinct mechanisms may be at play: a general feature detection process may explain the rapid identification of evolutionary threatening cues, whereas specific feature detection seems more suitable for modern threatening stimuli.

There is no consensus whatsoever regarding whether the attentional bias towards threats is due to the above-mentioned fear module or if it is mediated by feature detection. Studies using visual search methods have shown that detecting curvilinear shapes, such as the body of a snake, is faster compared to straight or zigzag lines (LoBue et al., 2014; Van Strien et al., 2016; Wolfe et al., 1992). Additionally, an attentional advantage toward downward-pointing V shapes, which geometrically resemble the head of snakes, has also been noted (Larson et al., 2007). These findings are in line with the general feature detection theory, which postulates that threatening stimuli stand out due to their distinct visual features, encompassing aspects like shape, movement, or sound (Coelho & Purkis, 2009; Davey, 1995). This theory posits that the initial implicit processing of threats is activated by visual features, particularly shape. Consequently, a neutral object with visual similarities to a threat (e.g., a worm that is similar to a snake) is expected to evoke a similar processing advantage. This is possible through the salience network, which is activated based on the perceived level of subjective salience, be it cognitive, homeostatic, or emotional in nature. It engages in the bottom-up detection of salient events, seamlessly transitioning between various networks to enhance access to attention and working memory once a salient event is detected. This involves the interplay of the already mentioned amygdala, the anterior and posterior insula for autonomic reactivity to salient stimuli, along with robust functional connection with the anterior cingulate to expedite swift access to the motor system (Goulden et al., 2014; Yin et al., 2018). This is also in line with the theory of survival circuits introduced by LeDoux (2012). These circuits function as sensory-motor integrative mechanisms designed for adaptive purposes. They are finely tuned to identify information relevant to environmental challenges and opportunities. Utilising this information, they govern behavioural responses and internal physiological adjustments aimed at resolving the situation. Some stimulus features interlinked with threat are a trigger for these circuits, so the organism does not need to process complex perceptual patterns, which would take a longer time (e.g. rats are able to identify predators by just their odour, humans are able to recognize some emotions by looking at the eyes alone).

Taking all of this together, threatening stimuli wield a significant impact on attention, paralleling the attention-grabbing nature of visually salient stimuli. Whether analysed through the frameworks of general feature detection or the fear module theory, there appears to be a pronounced bottom-up pull towards threatening cues. Examining this phenomenon from an inhibition perspective is crucial for a nuanced understanding of how top-down and bottom-up mechanisms interplay in threat processing. The inquiry into whether threatening cues can undergo inhibition, like visually salient cues in certain scenarios, sparks curiosity.

For this narrative review, we selected studies that used threatening stimuli as task-irrelevant distractors. Even though the main interest of this dissertation is not the attentional allocation modulated by emotional faces, we included studies that used threatening or angry faces as threatening distractors as well, given the scarcity of experiments that use stimuli with no social relevance (e.g. snakes, spiders). In addition, we are not discussing experiments involving participants with various anxiety disorders, as the focus of our interest is the normal population. In our analysis, we explored the potential inhibition of threatening information from three distinct perspectives: (1) investigating how threatening stimuli differ from stimuli evoking other emotions, (2) comparing the feasibility of inhibition in tasks of varying difficulty levels, and (3) introducing the influence of top-down goals in the inhibition of threat. The first perspective aimed to distinguish the unique nature of threatening information in human information processing relative to other emotional stimuli. The second and third viewpoints were formulated in response to the findings of our systematic review. (Reminder: feature-based search might make goal-driven control possible if certain circumstances are met, like a smaller set size or easier task.)

3.1 Threatening Distractors vs. Other Emotional Distractors

Previous research has demonstrated varying prioritisation among emotional dimensions, with threatening stimuli potentially holding greater significance than other categories (Humphrey et al., 2012, Zsidó et al., 2018). From an evolutionary standpoint, objects with emotional significance play a crucial role in our survival, providing essential cues for actions related to defence or reproduction (Cacioppo et al., 1999). Emotionally charged objects, irrespective of their valence, also often carry personal relevance (Humphrey et al., 2012). These cues activate survival circuits and receive priority in neural processing, potentially interrupting ongoing activities to prepare the organism for appropriate reactions (LeDoux, 2012). For threatening stimuli, the bias is likely attributed to the evolutionary advantage associated with the accelerated detection of threats, enhancing one's chances of survival (LeDoux, 2014; Öhman & Mineka, 2003).

In an ERP study (Burra et al., 2019), participants were tasked with identifying an image of a specific flower amidst similar ones, with either a neutral (leaf) or a threatening (spider) stimulus presented as a distractor. As previously mentioned in the systematic review of attentional allocation to salient stimuli, the N2pc component, occurring between 200-300ms post-stimulus, serves as a valuable indicator of attentional selection. According to the attentional allocation hypothesis, this component signifies attention directed toward the stimulus (Luck & Hillyard, 1990) while the attentional selection hypothesis posits that the amplitude of the component is influenced by the effort required to inhibit surrounding distracting stimuli, with greater effort correlating with a higher amplitude (Luck & Hillyard, 1994; Czigler et al., 2006; Czigler, Sulykos, & Kecskés-Kovács, 2014). Another reliable marker is the Pd component (distractor positivity), representing a contralateral lateral-occipital positive wave occurring between 300 and 350ms after the presentation of the stimulus. This electrophysiological signal signifies attentional inhibition and is evident during the presentation of distracting stimuli (Hickey, Di Lollo, & McDonald, 2009; Sawaki & Luck, 2010). The results showed increased behavioural interference, indicated by slower reaction times and reduced accuracy, when a threatening distractor was present compared to a neutral one. ERP results revealed N2pc was present only for target detection, and Pd was present for both distractors. This suggested inhibition by participants, but with a delayed suppression for spider distractors. A second experiment ruled out visual differences as the cause of delay, involving a foveal task where participants were instructed to locate a missing pixel on the fixation cross. The distractors remained the same as in the first experiment (flowers and one spider or leaf singleton). This manipulation reduced attention to the peripheral search display. While the amplitude of the posterior positivity remained the same for spider and leaf distractors, the timing of suppression differed. This suggests that the effects of attentional selection and suppression combined, causing the delay in suppression for threatening stimuli.

Zsidó et al. (2023) aimed to compare the impact of stimuli with different emotions on orienting and executive attentional processes. In two eye-tracking studies, participants were exposed to emotionally charged (threatening, nonthreatening negative, positive) and neutral pictures as distractors during a visual search task under different cognitive load conditions (easy, hard). Behavioural findings indicated that participants were slower to locate the first target number (number 1) when the distractor was threatening, but overall task completion times were accelerated in this condition compared to other emotional valences. Moreover, participants directed their gaze toward threatening distractors earlier and for longer durations, especially under more challenging task conditions. This pattern was not observed for positive and nonthreatening images, suggesting that threatening stimuli indeed hold a distinctive prominence, aligning with prior studies emphasising the acceleration of processing of threatening stimuli, potentially driven by differential engagement of brain circuits. Zsido et al. (2018) argued that, concerning threatening stimuli, the arousal stimulation effect posits that although irrelevant threatening stimuli may initially hinder performance by capturing attention, the heightened arousal they induce can potentially offset this negative impact, leading to improved performance compared to when irrelevant neutral stimuli are presented. The elevated arousal associated with threatening stimuli might stimulate the cognitive system, facilitating the rapid allocation of cognitive resources to the task and minimising distraction interference.

O'Toole et al. (2011) utilised a flanker task at two difficulty levels (easy and hard) as well, assessing alerting, orienting, and executive attention. Using four cue conditions (no cue, double cue, centre cue and spatial cue), participants were signalled the approaching presentation (alerting) or location (orienting) of the task. Participants were tasked with responding to the direction (either right or left) of a central arrow surrounded by either four arrows facing the same direction as the central arrow (congruent flankers) or four arrows facing the opposite direction (incongruent flankers). In the easy task, the flanker was presented on the screen until participants responded, with a maximum duration of 1700ms. In the hard task, the flanker was removed after 100ms, but participants had the remaining 1600ms (a fixation cross was presented) to provide a response. Apart from this temporal distinction, there were no other variations between the tasks. Before each trial, an emotional face (angry, fearful, sad, happy or neutral) was presented at the centre of the screen. The results revealed that, in the easy task only, task-irrelevant threatening emotional faces enhanced orienting compared to nonthreatening faces, irrespective of stimulus duration. However, these effects did not persist in the difficult condition. When analysing both conditions together, duration effects emerged, indicating that longer stimulus durations led to greater interference, though in a nonlinear manner. The findings highlight the facilitation of attention by threat-relevant emotional stimuli in tasks with low cognitive load, emphasising the importance of considering various task parameters, like difficulty.

In conclusion, when compared to other emotional information (e.g., positive, nonthreatening negative, and neutral stimuli), threatening distractors tend to induce behavioural interference in tasks (Eimer & Kiss, 2007; O'Toole et al., 2011, Burra et al., 2019; Zsidó et. al., 2018, 2023). In certain instances, the presentation of threatening stimuli may elicit the arousal stimulation effect, leading to improved performance. On a neural level, it appears that threatening distractors also undergo inhibition, albeit with a delay compared to neutral distractors.

3.2 Threatening Distractors in Easy vs. Hard Tasks

As demonstrated in O'Toole and colleagues' (2011) study, task-irrelevant threatening faces facilitated orienting only in the easy task, suggesting that under conditions of lower cognitive load, goal-driven control can override stimulus-driven processes. Building on this insight – as observed in our systematic review – where a smaller cognitive load (e.g., smaller set-size (Wang & Theeuwes, 2020; Stilwell & Gaspelin, 2021) or a shorter presentation time of irrelevant cues (Carmel & Lamy, 2015) allowed goal-driven control to prevail, we aimed to explore how this dynamic translates to the inhibition of threatening salient distractors in both easy and hard tasks.

Eimer and Kiss (2007) utilised the N2pc component as an electrophysiological measure to explore whether attentional selection is influenced by the presence of fearful faces, even when these faces are entirely unrelated to the ongoing task. Participants were engaged in detecting infrequent luminance changes in a central fixation cross, while concurrently faced with stimulus arrays featuring a face singleton (a fearful face among neutral faces or vice versa) to the left or right side of the task. In trials lacking a target luminance change, the N2pc was triggered by fearful faces located near fixation, whether they were presented as singletons or not. This finding underscores that task-irrelevant fearful faces can alter the spatial distribution of attention. Interestingly, when face arrays coincided with a target luminance change, the N2pc response to fearful faces was diminished, indicating that concurrent target processing mitigates attentional capture by emotionally salient stimuli. The reduction in N2pc observed during these trials implies that the existence of a target, along with the processes of target identification, response selection, and response execution, diminishes the capacity of emotionally salient peripheral stimuli to seize attention (Eimer & Kiss, 2007).

In an MEG study, Fenker et al. (2010) analysed the modulation of the N2pc component by the expression of neutral or fearful faces. Subjects performed a visual search task where each frame had two double-coloured bars in orthogonal orientation within each visual field, accompanied by face photographs. Subjects identified the location of a specified colour in the target combination and ignored the irrelevant horizontal bar. The task helped focus attention on the left or right visual field. The emotional expression in the faces varied systematically between visual fields relative to the target visual field. Four emotional conditions were created: neutral in both visual fields, negative in the target visual field, negative in the opposite visual field, and negative in both visual fields. This allowed for the assessment of the effect of lateralized emotional facial expressions on event-related magnetic field responses concerning attentional focusing on the search target (target-related N2pc). Although the bar stimuli were superimposed onto task-irrelevant faces, they did not cover critical facial features. Lateralized fearful faces elicited an N2pc response in the ventral extrastriate cortex, distinct from the N2pc related to target selection in visual search. Despite their neural influence, fearful faces did not significantly affect behavioural performance. A subsequent MEG experiment with reduced task demands showed that lateralized fearful faces still elicited an N2pc response independent of the search target. However, this time, behavioural performance was significantly influenced, suggesting that behavioural effects emerge when sufficient attentional resources are available, aligning with the perceptual load theory. The findings indicate that irrelevant fearful faces automatically influence attentional processing in extrastriate visual cortex, yet this might not necessarily translate to behavioural effects when attentional resources are consumed by the primary search task.

Zsidó et al. (2022) investigated the impact of task-irrelevant threatening stimuli on the salience network and executive control of attention under conditions of low and high cognitive load. Participants were presented with neutral or threatening pictures of varying arousal levels as distractors in parafoveal and peripheral positions while engaged in a number search task, similar to the one previously presented (Zsidó et al. 2023). The results revealed that task-irrelevant distractors mainly influenced behavioural measures under conditions of high cognitive load. Moderate-arousal threatening images slowed reaction times for finding the first number, but this effect was counteracted by high-arousal threatening stimuli, resulting in overall shorter search times. Eye-tracking measures indicated that participants fixated on threatening pictures later and for shorter durations compared to neutral images. Arousal induced by threatening stimuli has the potential to offset their distracting impact by enhancing visual search processes under heightened arousal conditions (Zsidó et al., 2022).

As evident from the above, there is conflicting evidence regarding the impact of task difficulty on the inhibition of threatening stimuli. Certain studies suggest that in easy tasks, behavioural interference is present, but, under higher cognitive load, this effect diminishes and the inhibition of threatening distractors becomes stronger (Eimer & Kiss, 2007; Fenker et al., 2010). This pattern aligns with the perceptual load theory (Lavie, 1995, 2000; Cartwright-Finch & Lavie, 2007), proposing that attention directed toward a primary task inhibits the perception of task-irrelevant stimuli (early selection) when the task-related processing demands a high perceptual load. Conversely, when processing task-related stimuli involves a low perceptual load, surplus capacity unintentionally spills over to the perception of irrelevant stimuli (late selection). However, neural data indicates that threatening distractors produce differences in both easy and hard tasks (Fenker et al., 2010), yet this does not consistently translate into behavioural interference in easy tasks. In contrast, Zsidó et al. (2022) discovered that task-irrelevant distractors influenced behavioural measures more during a high cognitive load task than a low cognitive load task. Notably, the distinction between these studies lies in the nature of the distractors, with those reporting behavioural interference in easy tasks using threatening or frightened faces, while Zsidó et al. (2022) employed socially irrelevant stimuli like snakes.

3.3 Threatening Distractors vs. Top-Down Goals

In our systematic review, we found that for the successful inhibition of physically salient singletons, it is essential that singleton selection strategy should not dominate; instead, a feature-based search strategy must be employed during the task (Gaspelin, Leonard, & Luck, 2017). This aligns with the contingent involuntary attentional orientation theory, arguing that only salient stimuli capable of being integrated into the task-induced attentional set can capture attention (Folk et al., 1992). Therefore, our focus in selecting studies was to compare how inhibition functions when the presence of threatening distractors aligned or misaligned with top-down goals.

Vromen et al. (2015, 2016) proposed that goal-driven modulation predominantly influences delayed disengagement from threat. A spatial cueing task was employed to separate delayed disengagement from attentional capture by precisely manipulating attentional focus at target onset. Participants were to detect target stimuli (two green animal silhouettes). Non-target stimuli were also included: five white animal silhouettes. Varying top-down goals were established by instructing participants to identify green bird/fish targets (Experiment 1) or green spider/cat targets (Experiment 2) among white animal non-targets. Delayed disengagement from a non-target spider occurred only when the spider was part of the target set, not when it was irrelevant to the task. This supports the idea that threat stimuli may not automatically override goal-driven attentional control, and the prolonged processing of threatening distractors is not mandatory.

Another study (Vogt et al., 2013) investigated whether attentional bias towards goal-relevant information persists in the presence of threatening stimuli, across three experiments using a dot probe task combined with a concurrent goal-inducing task. In each dot probe task trial, a black fixation cross appeared, situated in the middle of the screen within a white square. Two white rectangles were positioned on the screen, above and below the fixation cross. Cues and probes were presented within these rectangles. After 500ms, two cue pictures were displayed for 350ms. Following cue offset, a black square probe appeared, and participants had to locate it. The trial concluded upon a response or after 1500ms from the probe onset. In the goal task trial, a picture appeared in the middle of the screen for 250ms, replaced by a red question mark. Participants had to respond to the goal-relevant picture by pressing the spacebar with the left hand, and the trial ended either with the response or after 2000ms from the question mark onset. Correct reactions to the goal-relevant picture were followed by correct feedback, while incorrect reactions received error feedback. In the dot probe task, participants were instructed to focus on the fixation cross and quickly respond to the probe's location. In the goal task, participants were informed that a single picture would appear after responding to the probe. The pictures were taken from the International Affective Picture System (Lang et al., 1999), one from a set of two neutral and two threatening categories. One was always the goal-relevant picture, while the others were comparison pictures. If it was the goal-relevant picture, they were instructed to press the spacebar with the left hand when the question mark appeared. The instructions for the goal task emphasised that speed was not crucial for this task. Trials of the dot-probe and goal task alternated. When the goal-relevant picture had a threatening theme, the dot probe trials included goal versus threat, goal versus neutral, threat versus neutral, and neutral versus neutral. When the goal-relevant picture was neutral, the dot probe trials comprised goal versus threat, goal versus neutral, threat versus neutral, and threat versus threat. Experiment 1 revealed that attentional orientation to goal-relevant pictures, irrespective of whether they co-occurred with neutral or threatening pictures. The nature of goal-relevant pictures (threatening or neutral) did not impact the results. Experiment 2 replicated these findings in highly trait-anxious participants. Experiment 3 remained the same with a few modifications. The goal-relevant stimulus, threatening stimulus, and neutral stimulus were replaced with three coloured patches (pink, yellow, and orange). The functions of these patches were counterbalanced between subjects. Additionally, 18 filler stimuli were introduced to the goal task, presenting relevant stimuli less frequently to avoid habituation. These fillers included seven coloured patches and eleven neutral pictures from the International Affective Picture System (Lang et al., 1999), featuring various shades of green, brown, and grey. Participants demonstrated automatic attention deployment to stimuli aligned with a temporary goal, even in the presence of threat signals. These results support the notion that an individual's current and temporary goals play a pivotal role in guiding early attentional processes (Vogt et al., 2013).

Brown, Berggren and Forster (2020) combined the contingent capture and emotion-induced blink paradigms in an RSVP task with positive or threatening target search goals. Participants were instructed to either find a “cute” (=baby or pet animal, positive target) or “threatening” (=predator or poisonous animal, threatening target) animal among other neutral animals’ pictures. The target image appeared on the centre of the screen but the trials occasionally involved distractor pictures (neutral, positive, and threatening) on the top and bottom of the screen. The results consistently showed that adopting a search goal for a threatening category induced involuntary attentional capture by irrelevant threatening distractors, while a positive goal led to capture only by positive stimuli.

In conclusion, inhibition appears most robust when threatening distractors align with top-down goals (Vromen et al., 2015, 2016; Vogt et al., 2013; Brown, Berggren, & Forster, 2020). In tasks where a threatening stimulus could also be a target stimulus, attentional capture occurs only in trials where participants are searching for a threatening target. Threatening distractors are disregarded when they deviate from the task's goal-set.

3.4. Discussion

Threatening stimuli exert a considerable influence on attention (Soares et al., 2009, 2014; Öhman et al., 2012; Humphrey et al., 2012; Zsidó et al., 2018), like visually salient stimuli (Desdimone & Duncan, 1995; Egeth & Yantis, 1997; van Zoest et al., 2004; Theeuwes, 2010; Gaspelin & Luck, 2017; Luck et al, 2021). This capability is facilitated by selectively evolved neural pathways that engage the amygdala, capable of rapid activation via the subcortical "low road" (LeDoux, 2000). The subcortical route contributes to stimulus discrimination, indirectly expediting the process of identification, which engages the visual cortical areas.

Investigating this phenomenon from an inhibition standpoint is essential for a nuanced comprehension of the interplay between top-down and bottom-up mechanisms in threat processing.

In our review, we examined the possibility of inhibiting threatening information from three perspectives: (1) we examined how threatening stimuli compare to stimuli of other emotions, (2) we compared the possibility of inhibition in easy and hard tasks and (3) we introduced the role of top-down goals in threat inhibition.

Threatening distractors seem to have greater influence on attention compared to neutral, positive and other negative but nonthreatening emotions. When compared to neutral distractors, results often indicate increased behavioural interference when a threatening distractor is presented (Eimer & Kiss, 2007; O'Toole et al., 2011, Burra et al., 2019; Zsidó et. al., 2018, 2023). ERP findings (Burra et al., 2019) revealed a posterior positivity for both threatening and neutral distractors, with a delayed suppression specifically observed for threatening stimuli. In an eye-tracking study (Zsidó et al., 2023), participants directed their gaze toward threatening distractors earlier and for longer durations than towards other distractors, all the while having overall better performance on the task. Other findings indicated that task-irrelevant threatening emotional faces facilitated orienting more than nonthreatening faces (O'Toole et al, 2019).

Zsidó et al. (2023) sought to compare the influence of stimuli with different emotional valences on orienting and executive attentional processes. In two eye-tracking studies, participants were exposed to emotionally charged (threatening, nonthreatening negative, positive) and neutral pictures as distractors during a visual search task. Behavioural results indicated that participants were slower to locate the first target number when the distractor was threatening, but overall task completion times were accelerated compared to other emotional valences. In addition, participants directed their gaze toward threatening distractors earlier and for longer durations, especially under more challenging task conditions. This pattern did not manifest for positive and nonthreatening images, highlighting the importance of threatening stimuli in capturing attention. The arousal stimulation effect (Zsidó et al. 2018) suggests that threatening stimuli may initially hinder performance, however, the heightened arousal they induce can potentially offset this negative impact, leading to improved performance compared to when irrelevant neutral stimuli are presented. This heightened arousal associated with threatening stimuli might stimulate the cognitive system, facilitating the rapid allocation of cognitive resources to the task and minimising distraction interference (Zsidó et al., 2018, 2020). However, this accelerated cognitive performance does not mean that threatening stimuli were successfully inhibited – on the contrary, their effect on attention was still greater than that of any other distractors', that is, it was enhancing performance instead of hindering it.

It also seems like that task difficulty has a big role to play in the struggle of inhibiting threatening information. In identical tasks of different cognitive loads or difficulty levels, it seems to be "easier" to ignore irrelevant threatening stimuli in the hard task than in their less difficult counterparts. In the study by Fenker et al. (2010), while both easy and hard tasks showed neural interference when threatening distractors were presented, behavioural interference emerged only in the task with reduced demands. Similarly, in the study of O'Toole et al. (2011), threatening faces facilitated attentional orienting relatively more compared to happy faces in the easier task, while in the hard task, attentional effect for the face categories did not emerge. Also, participants tended to get more distracted by threatening irrelevant stimuli when there was no target in the search array, while they successfully inhibited the distractors when the target appeared (Eimer & Kiss, 2007). This might be best explained by the perceptual load theory (Lavie, 1995, Lavie, & Fox, 2000; Cartwright-Finch & Lavie, 2007). In this model, directing attention to a primary task can inhibit the perception of task-irrelevant stimuli (early selection) when the task-related processing requires a high perceptual load, utilising all available capacity. In contrast, when processing task-related stimuli involves low perceptual load, any surplus capacity unintentionally spills over to the perception of irrelevant stimuli (late selection).

On the contrary, Zsidó et al. (2022) found that task-irrelevant distractors influenced behavioural measures during their high cognitive load task. Moderately threatening distractors significantly slowed reaction times in finding the first number on a number search matrix, however, eye-tracking measures showed that participants fixated on threatening images later and for a shorter time. Highly arousing threatening images accelerated task completion in this experiment as well. Participants completed the task of finding numbers one to ten more quickly when the distractor image was threatening. Findings did not reveal increased dwell time or faster attentional capture for threatening images, which aligns with the signal suppression hypothesis (Sawaki & Luck, 2010). This hypothesis suggests that top-down control mechanisms can suppress the signal of a salient stimulus, allowing goal-driven mechanisms to override its salience. In the easy task, suppression of threatening images was successful, while in the hard task, suppression was weakened due to comparatively limited resources.

Inhibition seems to be strongest when threatening distractors and top-down goals are aligning (Vromen et al., 2015, 2016; Vogt et al. 2013; Brown, Berggren, & Forster, 2020). In tasks where a threatening stimulus could be a target stimulus as well, attentional capture happens only in trials where participants are looking for a threatening target. Threatening distractors are ignored when they differ from the goal-set of the task, while other emotions might become more salient (e.g. positive target – distractor pairs (Brown, Berggren, & Forster, 2020)). This is in line with the theory of contingent involuntary orienting (Folk, Remington, & Johnston, 1992), saying that attention is attracted to a salient stimulus only when it aligns with the current attentional set, shaped by the explicit or implicit goals of the observer.

In sum, the influence of threatening stimuli on attention is evident, demonstrating a significant impact similar to visually salient stimuli. Threatening distractors tend to exhibit a greater impact on attention compared to neutral, positive, and other negative emotions (O'Toole et al., 2011; Burra et al., 2019; Zsidó et al., 2018, 2023). While initial suppression of threatening stimuli occurs usually in easier tasks, this effect diminished under higher cognitive loads (Eimer & Kiss, 2007; O'Toole et al., 2011; Fenker et al., 2010). However, there is also contradicting evidence saying that it is harder to inhibit threatening distractors under high cognitive load (Zsidó et al., 2022), although, in this case, behavioural interference shows in better task-performance. Notably, threatening stimuli's alignment with top-down goals strengthened inhibition (Vromen et al., 2015, 2016; Vogt et al., 2013; Brown, Berggren, & Forster, 2020), aligning with the contingent involuntary orienting theory (Folk, Remington, & Johnston, 1992) and the signal suppression hypothesis (Sawaki & Luck, 2010). While it seems like that the top-down suppression might work for threatening distractors in very limited circumstances (just like in the case of physically salient ones), there might be a delay of inhibition caused by their affective relevance, as well as a stimulating effect due to their level of arousal (Zsidó et al., 2018, 2023).

Our current study's findings match those of our systematic review, revealing that the interplay between stimulus-driven and goal-driven processes occurs when threatening distractors are presented, much like the scenario with physically salient stimuli. Threatening distractors exhibit a heightened impact on attention compared to other emotions (Eimer & Kiss, 2007; O'Toole et al., 2011, Burra et al., 2019; Zsidó et. al., 2018, 2023). In low cognitive load tasks involving socially relevant threatening stimuli, such as angry faces, behavioural interference is observed. However, under higher cognitive load, this effect diminishes, and the inhibition of threatening distractors becomes more pronounced (Eimer & Kiss, 2007; Fenker et al., 2010). Neural data shows that irrespective of cognitive load, threatening distractors mediate attention in both easy and hard tasks (Fenker et al., 2010), however, this doesn't consistently translate into behavioural interference in easy tasks. It also seems like that socially irrelevant threatening cues might have a slightly different effect on attentional processes than socially relevant ones, which would be an interesting topic for further investigations. Nevertheless, as we have seen with physically salient stimuli as well, we can say that the introduction of top-down goals to the task enhances the effective inhibition of threatening distractors.

It's important to note that, similar to studies on physically salient distractors, these findings may not perfectly model everyday life situations; rather, they aim to describe general truths about attentional processes. In real-world scenarios involving threatening information, inhibition may not be applicable, and these studies underscore the difficulty of overriding this response even in controlled laboratory tasks. Nevertheless, gaining insights into these processes can contribute to the understanding and treatment of animal phobias and certain anxiety disorders.

4. CAN THE PROCESSING OF TASK-IRRELEVANT THREATENING STIMULI BE INHIBITED?[2]

4.1. Introduction

The highly salient nature of threatening stimuli has long been recognized in a variety of psychological literatures. Many studies (Becker et al., 2011; Blanchette, 2006; Coelho et al., 2019; LoBue, 2010; Subra et al., 2017; Williams et al., 2006; Zsido, Csatho, et al., 2019; Zsido, Deak, et al., 2019) have observed faster reaction times to threatening compared to neutral stimuli (across a variety of tasks). Threatening objects are more salient not just when compared to neutral objects but also to stimuli of different valences, such as positive or negative nonthreatening items (Csathó et al., 2008; March et al., 2017; Williams et al., 2006; Zinchenko et al., 2017; Zsido, Bali, et al., 2022). This is likely because the perception of threats is an implicit (i.e., automatic) process that precedes other implicit (e.g., processing of valence) and explicit processes (e.g., evaluation) (March et al., 2018). This initial implicit processing is sensitive to both evolutionarily relevant threats, such as dangerous animals or situations (e.g., snakes, heights), and to acquired ones (e.g., guns, social groups). Hastened detection is made possible via the *brainstem-amygdala-cortex* neural alarm system (Liddell et al., 2005). Through this pathway, stimuli are evaluated without overt effort, resulting in fast orienting behaviours. This can equally occur in and out of attentional focus. In prior work (Bayle et al., 2009), quickened responses to threatening stimuli were observable even when the threatening item was presented in the peripheral visual field. However, to date, we still do not know whether visual features (e.g., shape) of the threatening stimuli

---

[2] This chapter is based on the following article:
Pakai-Stecina, D. T.; Hout, M. C.; Bali, C.; Zsidó, A. N. (2024). Can the processing of task-irrelevant threatening stimuli be inhibited? – The role of shape and valence in the saliency of threatening objects, *Acta Psychologica*, 243:104150.
Author contribution: **DTPS**: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Resources, Software, Writing – original draft, Writing – review & editing; **MCH**: Conceptualization, Formal analysis, Methodology, Supervision, Visualization, Writing – original draft, Writing – review & editing; **CB**: Investigation, Project administration, Software, Visualization, Writing – review & editing; **ANZS**: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

alone are sufficient to trigger the hastened processing that precedes all subsequent processing.

According to the *general feature detection theory,* threatening stimuli are salient because of their specific *visual* features, such as their shape, movement, or skin pattern (Coelho & Purkis, 2009; Davey, 1995). For instance, an EEG study (Van Strien & Isbell, 2017) showed that close-up pictures of snakeskin patterns elicit larger early posterior negativity compared to lizard skin and bird plumage pictures. Similarly, a recent behavioural study (Berggren, 2022) found delayed reaction times when the colour associated with angry expressions reappeared as a task-irrelevant distractor during a visual search task. Colours associated with nonthreatening expressions (i.e., neutral and happy) did not produce the same result.

Shapes associated with various threats also seem to be more salient than other visual features. A curvilinear shape (such as the body of a snake) can be considered one of these salient features that is detected automatically, facilitating an immediate response to threats. Indeed, multiple studies have shown that curvilinear shapes are detected faster in visual search tasks compared to straight or zigzag lines (LoBue et al., 2014; Van Strien et al., 2016; Wolfe et al., 1992). Adding to the importance of shape as a visual feature, an advantage in processing for downward pointing *V*s (which has geometrical resemblance to the heads of snakes) has also been observed (Larson et al., 2007). The advantage of certain visual features strongly associated with threats may be caused by the valence and arousal the shape evokes. Nevertheless, the *general feature detection theory* contends that the initial implicit processing of threats is triggered by visual features such as shape, and, therefore, a neutral object that is visually very similar to a threat (such as a worm) should elicit a similar advantage in processing.

By contrast, the *fear module theory* (Mineka & Öhman, 2002; Öhman & Mineka, 2001) postulates that the saliency of threatening objects is due to their *affective features* (i.e., valence and arousal elicited by the stimulus). According to the *theory of arousal biased competition* (Mather & Sutherland, 2011), emotional arousal is able to modulate cognitive processes and mental representations in order to enhance memory and bias selective attention. Based on these accounts, the initial implicit processing of threats is triggered by the emotional features of the stimuli and, therefore, an emotionally neutral object that is visually similar to a threat should not have the same advantage in processing as an actual threat.

It is certainly possible that particular visual features (such as shape) have an advantage because they evoke the same emotional valence and arousal as the actual threats they are resembling (Anderson & Kim, 2019; Le Pelley et al., 2017; Schmidt et al., 2015). For instance, a previous study (Schmidt et al., 2015) examined the automatic capture of attention by physically salient stimuli and emotionally significant stimuli. Specifically, the authors investigated whether a salient neutral stimulus (a colourful diamond shape) – when associated with fear through conditioning – could capture attention in visual search. The experimental procedure involved pairing one stimulus (CS+) with an electrical shock, while another stimulus with the same physical characteristics (CS-) was never paired with a shock. After conditioning, participants performed a target search task, where irrelevant CS+ or CS- stimuli were occasionally presented. The findings revealed that the presence of an irrelevant distractor previously associated with fear significantly impaired search performance compared to a distractor lacking fear association. These results suggest that fear associations learned through conditioning have the power to capture attention, even when individuals attempt to disregard them. However, it is equally important to investigate the ecological validity of these findings (to ensure their applicability and generalizability to real-world contexts) by using natural fear associations instead of conditioned ones.

In a recent study of ours (Zsido, Stecina, et al., 2022), we investigated the impact of threat and visual similarity on target discrimination. Participants completed a Rapid Serial Visual Presentation task, where the stream consisted of threatening and visually similar (but nonthreatening) objects. During the task, participants were presented with six pictures under four different conditions: (1) pictures with the same arousal and shape (e.g., hairdryers), (2) pictures with the same arousal but different shapes (guns and snakes), (3) pictures with different arousal but similar shapes (guns and hairdryers), and (4) pictures with different arousal and dissimilar shapes (snakes and hairdryers). After each RSVP stream, participants saw two pictures and had to choose which one appeared in the stream (i.e., the target). Our results showed that when shape was a sufficient feature by which to discriminate the target from the other items in the stream (e.g., a snake among hairdryers), there was no effect of arousal on performance. Thus, shapes associated with threat alone (irrespective of affective value) yielded faster responses. Participants did rely on arousal, however, when all stimuli in the stream were visually similar (e.g., a snake among worms). Working memory was less impaired in the dissimilar conditions which could have made the discrimination easier. However, this prior study was concerned with the competition for visual working memory resources rather than elucidating the root cause of attentional biases to threats, per se.

Sawaki and Luck (Sawaki & Luck, 2010) more directly addressed attentional biases, though not in the context of threats. These authors propose a hybrid model to describe how the inhibition of an "attend-to-me" signal works when task-irrelevant *visually salient* (but emotionally neutral) distractors are present. The *signal suppression hypothesis* claims that a salient stimulus in the visual field creates its potentially attention-grabbing signal regardless of its relevance to the observer's goals. This signal, however, can be actively suppressed by the observer before attentional capture with the help of top-down control (Sawaki & Luck, 2010, 2011). In their ERP study (Sawaki & Luck, 2010), participants were looking for a letter in one of two areas of the display; some trials included irrelevant colour singletons and in the control trials, all letters were of the same green or red colour. This arrangement was organised such that a red salient distractor was presented amongst green stimuli or vice versa. Task-irrelevant salient singletons did not create signals for attentional deployment (indicated by the N2 posterior contralateral signal) but they did elicit signals of attentional inhibition (indicated by a distractor positivity signal) both in the attended and unattended areas.

In a more recent eye-tracking study (Gaspelin et al., 2017), participants were instructed to report the orientation of a line within a target stimulus, which was placed among distractors of heterogeneous shapes, including one (salient) distractor of a different colour. Singleton capture was discouraged by having participants look for the same target shape throughout the whole procedure. Results showed that it was less likely for the first fixation to land on the singleton distractor than on a non-singleton one (Gaspelin et al., 2017; Gaspelin & Luck, 2018). The authors also found that if active suppression of irrelevant singletons was promoted (simply by participants being told to ignore it), overt attentional shifts (i.e., oculomotor capture or direct fixation) to irrelevant salient singletons were less likely to happen than to non-salient distractors. Thus, we are clearly capable of attentional control through goal-directed, top-down mechanisms (Zinchenko et al., 2020). It has been suggested that goal-directed inhibition is capable of downregulating the emotional reactions caused by the automatic evaluation of emotional (including threatening) cues (Mogg & Bradley, 2018). That said, it has yet to be shown whether or not such signal suppression mechanisms apply to the inhibition of emotionally salient (rather than visually salient) stimuli.

The neural basis of behavioural interference caused by threat cues (and their subsequent inhibition) can be well-observed with tasks whereby threatening stimuli are presented as task-irrelevant distractors. In one such ERP study (Burra et al., 2019), participants were asked to find a specific flower image among other similar flowers and either a neutral (leaf) or a threatening (spider) distractor. In each trial, six stimuli were presented in a circle (following a centrally presented fixation cross). Behavioural interference (evidenced by slower RTs and lower accuracy) was larger when a threatening distractor was present compared to when a neutral one appeared. Although ERP results showed a posterior positivity for both distractors (indicating that both threatening and neutral distractors were inhibited by the participants), the inhibition was delayed (i.e., there was a longer offset latency of the P_D) for the spider distractors. The second experiment of the same study (Burra et al., 2019) excluded the possibility that the delayed suppression was due to visual differences between the spider and leaf distractors. In this experiment, although a similar display of six distractors was used, participants completed a foveal task where they had to find a missing pixel on the fixation cross, thereby reducing attention to the peripheral search display. Again, the amplitude of the posterior positivity was the same for the spider and leaf distractors, but the timing of suppression was different. These findings suggest that attentional selection and suppression combined, inducing the delay in suppression (Burra et al., 2019). That is, threatening stimuli can be inhibited, but at the cost of a delay relative to neutral distractors. However, we still do not know whether this attentional capture by threats is caused more by visual or affective features. Further, it is unclear how suppression operates across the entire visual field, as prior work did not manipulate the distance between distractors and the target.

In the present study, across two experiments, our overarching goal was to test whether attentional capture by threatening stimuli was more likely the result of the stimuli's visual or affective features. Further, we sought to test whether the distance between a distractor and the target has an effect on attentional orientation or inhibition. This second question is important because it has been previously shown that threatening (compared to neutral) stimuli presented outside the centre of vision divert attentional resources otherwise dedicated to foveal processing (Carretié et al., 2017; Soares et al., 2017). On the one hand, visual features (such as shape) associated with threat have been shown to be sufficiently processed in peripheral vision (Gao et al., 2017). On the other hand, in an fMRI study (Almeida et al., 2015), amygdala activation was only observed for true snake pictures and not for fake ones (when both were presented in the periphery).

In Experiment 1, we used behavioural measures (reaction times and accuracy) in a visual search paradigm; in Experiment 2, (as an extension of Experiment 1), we recorded eye movements to provide more insights into the underlying mechanisms responsible for attentional biases towards threats[3]. Our first hypothesis was that threatening objects (when employed as task-irrelevant distractors) are hard to inhibit primarily because of their affective features. Therefore, we predicted that distractors with affective features would have greater interference on task-performance, and that participants would fixate on them more (and for longer) compared to visually similar distractors without affective features. Our second hypothesis was that this effect would be independent of the distance between the distractor and the target when the distractor had affective features, but

---

[3] Due to a technical issue with the software used to record the experiment, we could not reliably extract button press results in Experiment 2, which precludes us from presenting them in this paper.

that when distractors were emotionally neutral (but visually similar to threats), the effect would decrease as the distance between targets and the distractor increased.

4.2. Methods

In Experiment 1, we used a standard visual search task similar to a previously published experiment (Hout et al., 2015). Participants had to locate a neutral target from a general category (i.e., a lock or butterfly) among scattered photographs of real-world neutral objects (e.g., a ball, a doll, a dog). In half of the trials, one of the distractors was a “special distractor” belonging to either a *threatening* category (snake, gun) or a *nonthreatening* category that was visually similar to the threatening categories (worm, hairdryer). For ease of exposition, the latter category will be referred to as nonthreatening distractors. Participants did not have knowledge about this manipulation. We also manipulated the distance between the target and the special distractor by having it presented close to or far from the target location. Experiment 2 was an extension of Experiment 1 that added the monitoring of eye-movements. In Experiment 1, participants completed the task in small groups (but at separate computer stations) and we only recorded reaction times (RTs). In Experiment 2, participants were assessed individually, and we recorded their eye-movements throughout the task.

4.2.1 Participants

The required sample size for this experiment was determined by computing estimated statistical power based on previous studies of singletons and threat suppression (Burra et al., 2019; Gaspelin et al., 2017; Gaspelin & Luck, 2018). The analysis ($f=.25$, $1-\beta > .95$, $r = .5$) indicated that the minimum required total sample size was 28. In our study, however, we wanted to examine an interaction between two factors which had not been investigated in these previous studies. Thus, our goal was to oversample, and we therefore collected data in one-week increments until the required sample size was exceeded. In Experiment 1, a total of 49 students (mean age = 19.9, SD = 1.52) participated.

The required sample size for Experiment 2 was determined based on the results (i.e., interaction effects) of Experiment 1. Estimated statistical power was computed with f=.40, β > .95, r = .5; the analysis indicated that the minimum required total sample size was 12. In Experiment 2, a total of 23 students participated (mean age = 20.1, SD = 1.43). Again, we sought to oversample (collecting data in one-week increments) because of the collecting of eye-tracking data, while in Experiment 1 we only observed behavioural results. Thus, both studies were adequately powered.

All participants were right-handed and reported normal or corrected-to-normal vision and normal colour vision. Data from one participant in both experiments was excluded because of failure to follow instructions. All participants were recruited through university mailing lists and received course credit for participation. Data was collected in Hungary, at designated laboratories in the building of the Institute of Psychology, University of Pécs. Our research was approved by the United Ethical Review Committee for Research in Psychology of Hungary and was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). All participants provided written informed consent.

4.2.2 Experimental Stimuli and Design

We created a visual search task using images downloaded from the Massive Memory Database (Brady et al., 2008; Hout et al., 2014) as neutral distractors and targets, and sourced a total of 64 images from the internet and from a previous study (Zsido, Stecina, et al., 2022) as special distractors. Half of these were threatening (snakes, guns) and the other half were nonthreatening (worms, hairdryers) objects. All images were resized to a maximum of 100x100 pixels (2.17° visual angle), maintaining the original proportions. For each trial, the 1920x1080 resolution screen was divided into four quadrants and each quadrant was divided into a 3x3 matrix of 9 equal-sized cells. Images were placed in 8 of the 9 cells (per quadrant;

total set size was 32) quasi-randomly[4]; image locations were randomly jittered within each cell in keeping with prior research (Hout et al., 2015; Hout & Goldinger, 2010, 2012, 2014) to give the appearance of scattering. This gave the overall appearance (to the participant) of a random assortment of pictures that was nevertheless controlled to ensure equal distribution of images across the screen, with no overlap of items (see Figure 4.1). Half of the trials were target-present and half were target-absent.

The crucial manipulation was that in half of all trials, a "special" distractor appeared in the form of a threatening or nonthreatening (but visually matched) object. We selected the threatening and nonthreatening stimuli to be as visually similar as possible in terms of overall shape, pose, colour, texture, luminance, image sharpness, and visual complexity. The images were then judged by a group of 20 independent students; pictures flagged as not visually similar were not used in the experiments. We also manipulated the distance between the target and this special distractor (on target-present trials) by locating the item in different parts of the matrix. There were very slight overlaps between the distance conditions because the cells, just like the screen, were rectangular (meaning that the diagonal diameter of the cells was greater than their height) and the objects jittered in each cell. In the close condition, targets and special distractors were placed in neighbouring cells; the distance between the centre of the target and the distractor thus fell between 4.02° and 8.04°. In the far condition, targets and special distractors were placed two to four cells away from each other; the distance here ranged between 6.69° and 19.93°. For a more detailed description of the sampling conditions, see Table 4.1.

---

[4] Images appeared random to the participants but were generated following a non-random sequence. That is, we fixed the place of the target and special distractors, then filled up the rest of the cells with distractors. Special distractors were selected in a way that only one exemplar per category could appear and all categories were cycled through evenly across trials.

Table 4.1 – Here we present a more detailed description of the sampling conditions. Number of pictures and trials broken down to blocks, distractor types and arrangement of target and special distractors.

Distractor type	Arrangement	Pictures / arrangements	Pictures / distractor types	Pictures / blocks	Pictures / task
Threatening	Only target, no special distractor	8	64	128	256
	Target and threatening distractor (close and far)	24			
	No target, threatening distractor	16			
	No target, no special distractor	16			
Nonthreatening	Only target, no special distractor	8	64		
	Target and similar distractor (close and far)	24			
	No target, similar distractor	16			
	No target, no special distractor	16			
Threatening	Only target, no special distractor	8	64	128	
	Target and threatening distractor (close and far)	24			
	No target, threatening distractor	16			
	No target, no special distractor	16			
Nonthreatening	Only target, no special distractor	8	64		
	Target and similar distractor (close and far)	24			
	No target, similar distractor	16			
	No target, no special distractor	16			

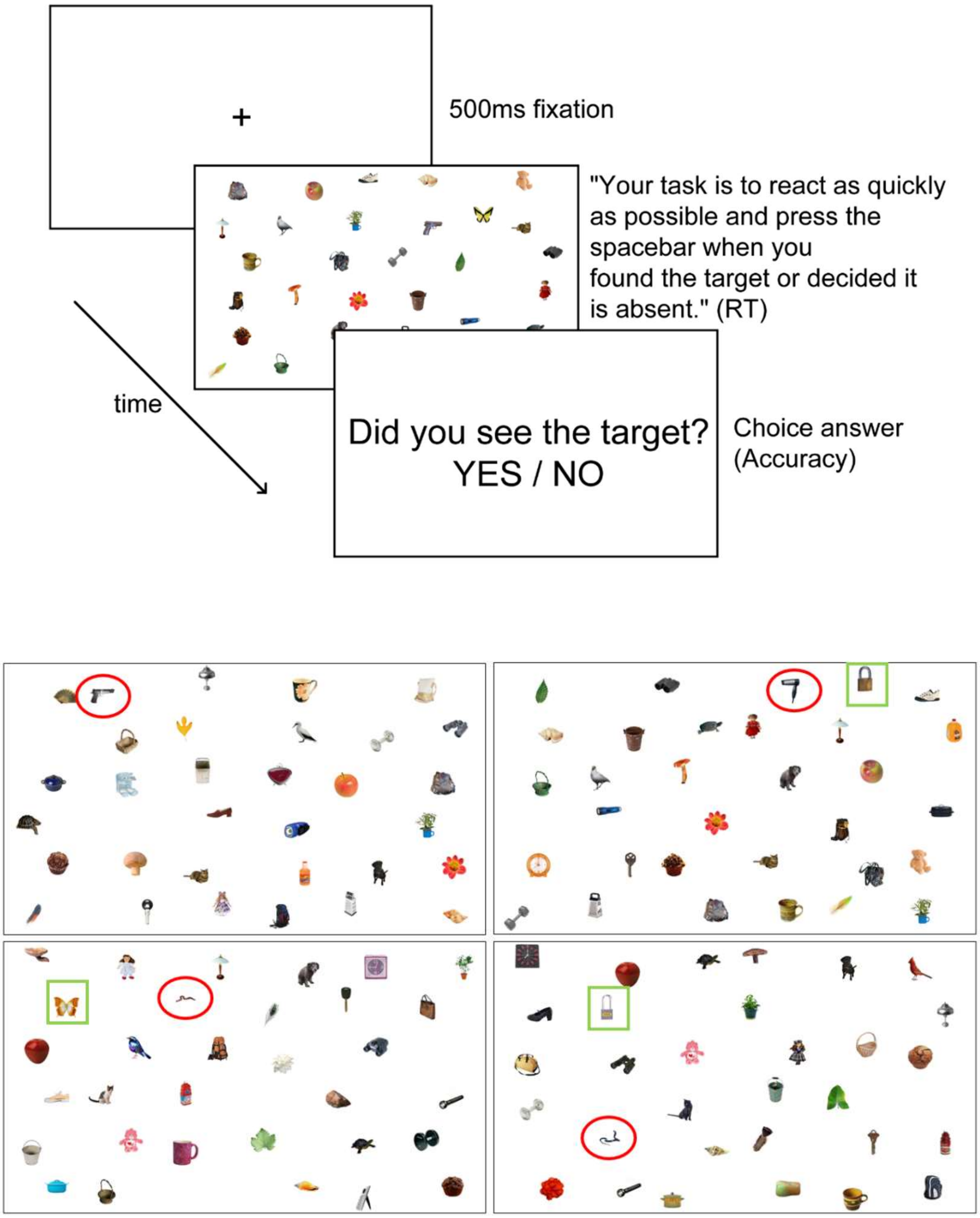

Figure 4.1 – The progression of events in a trial structure is shown in the top panel. First, a fixation cross was shown, then the visual search task was displayed until the participants indicated they had resolved their decision by pressing the spacebar. Lastly, a separate screen allowed them to indicate their decision regarding the presence or absence of the target. The bottom panel shows sample trials with special distractors sampled from the gun, hairdryer, snake, and worm conditions (clockwise starting from the top-left panel). Across the panels the various trial types can also

be seen: target-absent, target-present distractor close and target-present distractor far, moving clockwise from the top-left panel). Please note that while we highlighted targets with green squares and distractors with red circles for better visibility here, they were not used during the experiment.

4.2.3 Procedure

In Experiment 1, stimuli were presented and randomised using PsychoPy v3.0 software (Peirce, 2007). Data was collected in smaller groups, on up to 10 computers simultaneously (with identical hardware and software profiles) in a quiet room. Participants were seated in separated work-station booths, at approximately 60 cm from 21.5-inch LCD monitors with a resolution of 1920x1080, 16:9 aspect ratio, a refresh rate of 60 Hz, and colour depth of 16.7M. Experimental sessions were monitored by one research assistant. After verbal and written instructions, everyone completed a test-run of 10 trials (5 target-present, 5 target-absent) which were excluded from analysis. Participants could each ask questions before collectively starting the experiment. Participants completed two blocks of trials; in one block the search target was a lock and in the other it was a butterfly (with the order of blocks counterbalanced across conditions).

Each trial started with a black fixation cross on white background appearing for 500ms. Then, a search array was presented; participants were (earlier) instructed to react as quickly as possible and press the spacebar when they found the target or decided it was absent. After pressing the spacebar, the search array disappeared, and a question appeared on a blank screen prompting participants to report if they saw the target or not (‘y’ for ‘yes I saw the target’ and ‘n’ for ‘no I did not see the target’). Participants could give a yes/no answer by pressing the designated key respectively, without having to hurry. We used this response method similar to several previous studies (Hout et al., 2015; Hout & Goldinger, 2010, 2012, 2014) in order to separately (and more accurately) measure RTs, and to avoid mistakes stemming from mixing up the response keys. Participants were given the opportunity to take a couple of minutes of rest between the two blocks if they felt it was necessary. Each session of data collection lasted between 30 and 45 minutes.

In Experiment 2, the same stimuli were presented as in Experiment 1, presented on a 23-inch TFT colour monitor, with a resolution of 1920x1080, 16:9 aspect ratio, a refresh rate of 60 Hz, and colour depth of 16.7M. Stimuli were presented using Tobii Studio Gaze Analysis Software. Eye-movements were recorded using a Tobii Pro TX300 at a sampling rate of 300 Hz. A five-point calibration was completed before the experiment. Calibration accuracy was checked manually and repeated if it was not judged to be successful by the experimenter. To minimise head movements and increase the precision of the tracker, participants placed their heads on a forehead and chin-rest throughout the experiment. Data was collected one participant at a time and participants were seated in a small, dark room, approximately 60 cm away from the screen. The procedure and the task were identical to Experiment 1. The sessions lasted approximately 40 to 50 minutes per participant.

4.2.4 Statistical Analyses

Statistical analyses were completed using JAMOVI Statistics Program v2.0 (Jamovi Project, 2022). In Experiment 1, we examined RT and accuracy. Further, we computed Balanced Integration Scores (Liesefeld & Janczyk, 2019) which aim to control for the speed-accuracy trade-offs that are very common in visual search tasks and those using reaction time measurement in general. Balanced Integration Scores (BIS) integrate RTs and accuracy to show the relative performance and relative difficulty of the task (or condition). BIS is calculated by subtracting the standardised RT from the standardised proportion correct (PC) values (BIS = zPC – zRT). Lower BIS indicates worse performance and a harder task. In Experiment 2, we examined eye-tracking measures; in particular, the fixation count and total fixation duration on the special distractor (only including trials when there was at least one fixation). In all analyses presented here we focus on target-present trials (correct responses only). Regarding eye-tracking data, all trials with a special distractor present were analysed. The minimum gaze time required for an eye movement to count as a fixation was set to 50ms (the default setting for Tobii systems). Total fixation times were calculated on a trial-to-trial basis.

We first identified and removed outlier trials, defined as those greater than ±2 standard deviations of the group mean (resulting in removal of less than 1% of all the collected data) for each participant. We then checked to ensure that the distribution of the variables did not deviate significantly from a normal distribution (Shapiro-Wilk *p*s > .05). We performed 2x2 repeated measures ANOVAs to test the effect of Distractor Type (threatening, nonthreatening) and Distance from the Target (close, far) on performance and oculomotor measures. Tukey corrections were used to account for multiple comparisons. Main statistical results are presented in tables rather than embedded in the text to make the description of the results easier to follow. Our dataset (including computed study variables) is available on the Open Science Framework: https://osf.io/5pazw/.

4.3. Results

4.3.1 Experiment 1

4.3.1.1 Accuracy

We began by examining accuracy to test our prediction that distractors with affective features would cause greater interference to task-performance compared to visually similar distractors without affective features. See Table 4.2 for all statistical results, and Tables 4.6 and 4.7 for the descriptive statistics. This question is tested through the main effect of Distractor Type, which was not significant[5]. Next, we tested our second hypothesis that this effect will be independent of the distance between the distractor and the target when the distractor had affective features, but that when distractors were emotionally neutral (but visually similar to threats), the effect would decrease as the distance between targets and the distractor increased. The main effect of Distance was significant; participants were less accurate when a special distractor was close to the target compared to when it was far. Figure 4.2 shows the significant interaction between Distractor Type and Distance. For threatening distractors, the position of the distractor relative to the target did not affect the results. For nonthreatening distractors, participants were

---

[5] Further analyses comparing special distractor present and absent trials did not show a significant difference in accuracy between trials with affective feature distractors, visually similar distractors, and trials without such distractors.

less accurate when the distractor was close to the target compared to when it was far.

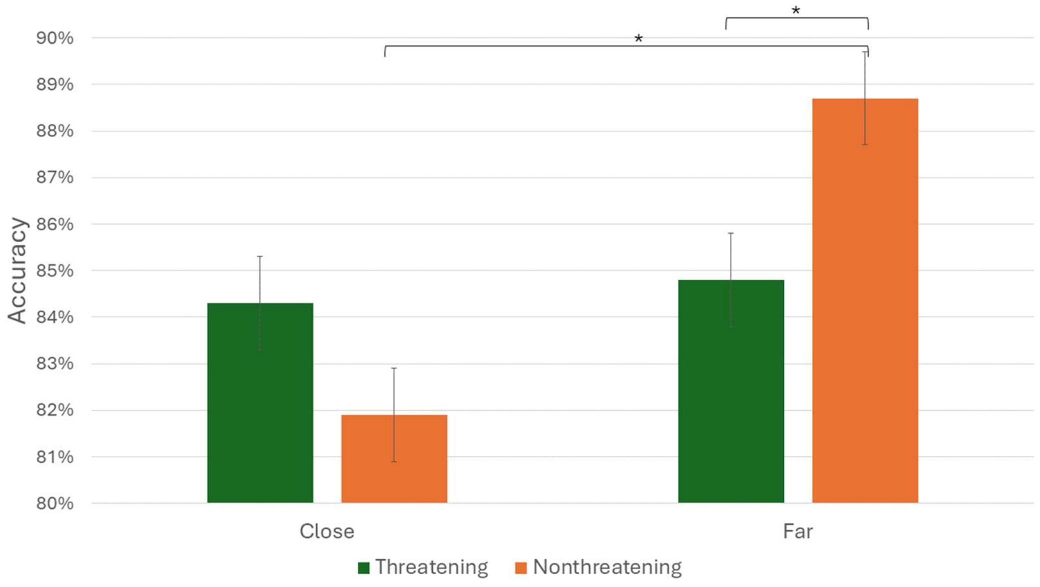

Figure 4.2 – Performance on the task as measured by accuracy in identifying the target (when a special distractor was present). Findings are presented across Distractor Type (green and orange bars) and Distance from the Target. Error bars represent one standard error of the mean.

Table 4.2 – Detailed statistical results for Experiment 1 (accuracy, reaction time, and BIS) with main effects, interactions, and follow-up simple effects.

Measurement	**Effect**	**df**	**F/t**	**p**	**η^2p**
Accuracy	Distractor Type	1,48	0.822	0.369	0.017
	Distance	**1,48**	**13.679**	**< .001**	**0.222**
	Interaction	**1,48**	**9.294**	**0.004**	**0.162**
	Simple main effects				
	Threatening Close – Threatening Far	48	-0.380	0.706	
	Threatening Close – Nonthreatening Close	48	1.615	0.113	
	Threatening Far – Nonthreatening Far	**48**	**-3.551**	**< .001**	
	Nonthreatening Close – Nonthreatening Far	**48**	**-4.494**	**< .001**	
Reaction time	**Distractor Type**	**1,45**	**5.32**	**0.026**	**0.106**
	Distance	**1,45**	**5.58**	**0.023**	**0.110**
	Interaction	**1,45**	**5.74**	**0.021**	**0.113**
	Simple main effects				

Measurement	Effect	df	F/t	p	η²p
	Threatening Close – Threatening Far	45	-0.159	0.874	
	Threatening Close – Nonthreatening Close	45	0.120	0.905	
	Threatening Far – Nonthreatening Far	**45**	**3.900**	**< .001**	
	Nonthreatening Close – Nonthreatening Far	**45**	**3.009**	**0.004**	
BIS	Distractor Type	1,47	2.57	0.116	0.052
	Distance	**1,47**	**12.39**	**< .001**	**0.209**
	Interaction	**1,47**	**8.64**	**0.005**	**0.155**
	Simple main effects				
	Threatening Close – Threatening Far	47	-0.349	0.729	
	Threatening Close – Nonthreatening Close	47	1.085	0.283	
	Threatening Far – Nonthreatening Far	**47**	**-4.074**	**< .001**	
	Nonthreatening Close – Nonthreatening Far	**47**	**-4.204**	**< .001**	

4.3.1.2 Reaction Time

We next examined reaction times to test our hypothesis that distractors with affective features would have greater interference on task-performance compared to visually similar distractors without affective features. Here, the main effect of Distractor Type was significant[6]. Participants were slower to find the target when there was a threatening distractor present compared to when a nonthreatening distractor was present. The main effect of Distance was also significant; participants were slower to find the target when a special distractor was close compared to when it was far. We then tested our second hypothesis that this effect will be independent of the distance between the distractor and the target when the distractor had affective features, but that when distractors were emotionally neutral (but visually similar to threats), the effect would decrease as the distance between targets and the distractor increased. The interaction between Distractor Type and Distance was significant. As shown in Figure 4.3, the effect of distance was not significant for threatening targets, while nonthreatening distractors slowed participants when they appeared close to the target.

---

[6] Further analyses comparing RTs on special distractor present and absent trials showed that participants were slower when a distractor with affective features was present compared to trials with a visually similar distractor. The difference between the affective feature distractor and no special distractors present conditions, and the two neutral conditions did not differ from each other.

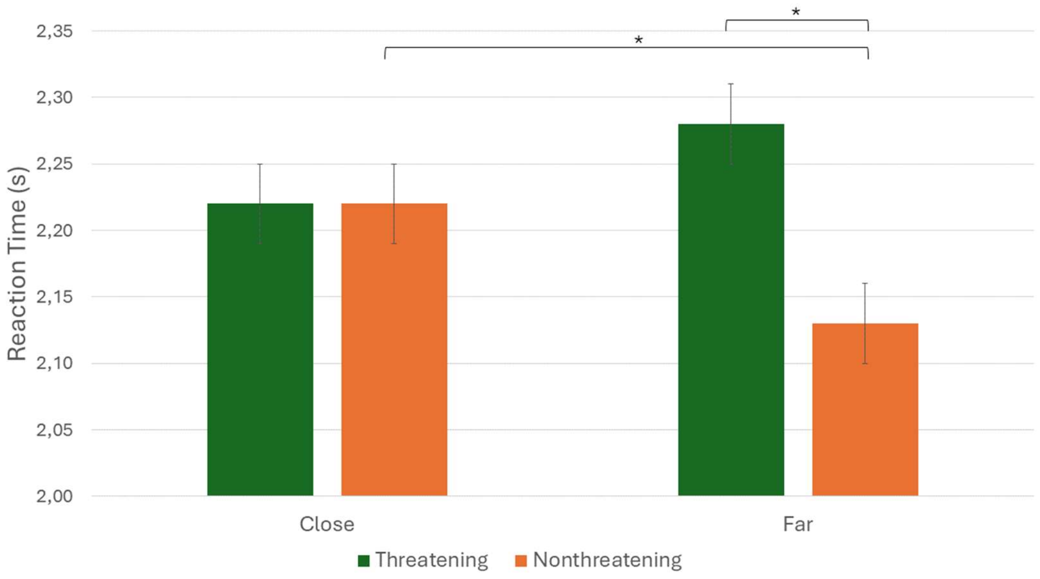

Figure 4.3 – Performance on the task as measured by the RT for finding the target (in seconds) on trials in which a special distractor was present. Findings are presented across Distractor Type (green and orange bars) and Distance from the Target. Error bars represent one standard error of the mean.

4.3.1.3 Balanced Integration Score

Finally, we examined BIS to help interpret the confluence of accuracy and RT. The main effect of Distractor Type was nonsignificant. The main effect of Distance was significant; the task was harder when a special distractor was close compared to when it was far. The interaction between Distractor Type and Distance was also significant. Figure 4.4 shows that the effect of distance was not significant for threatening targets, while nonthreatening distractors only made the task harder for participants when they appeared close to the target.

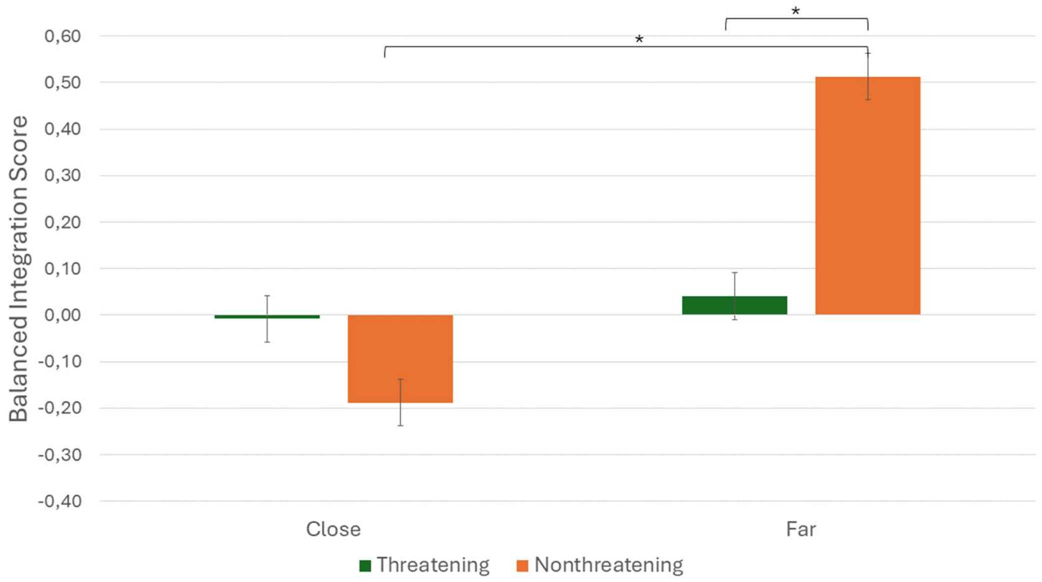

Figure 4.4 – Performance on the task as measured by BIS for finding the target on trials in which a special distractor was present. Findings are presented across Distractor Type (green and orange bars) and Distance from the Target. Error bars represent one standard error of the mean.

Taken together, our first hypothesis was not entirely confirmed. We only found evidence of distractors with affective features having greater interference on task-performance compared to visually similar distractors without affective features, when examining RTs – but not when examining accuracy and BIS. However, our second hypothesis was confirmed insofar as the performance of participants was worse when a special distractor was close to the target or a threatening distractor was present, while the task was easier with a nonthreatening target presented far from the target.

4.3.1.4 Target-Absent vs. Target-Present Trials

We performed 2x3 repeated measures ANOVAs to test the effect of Presence of the Target (present or absent) and Type of Special Distractor (threatening, nonthreatening visually similar, neither) on performance (indicated by RTs and accuracy). Main effects and interactions are reported separately, paired with relevant follow-up ANOVAs or t-tests to further investigate the significant interactions. Effect sizes are also presented: partial eta squared (η_p^2) for the ANOVAs. Tukey corrections were used to account for multiple comparisons.

4.3.1.4.1 Accuracy

The main effect of Presence of the Target was significant. As shown on Figure 4.5, participants were more accurate on target-absent compared to target-present trials. The main effect of Type of Special Distractor was nonsignificant. The interaction between Presence of the Target and Type of Special Distractor was nonsignificant. See Table 4.3 for all statistical results. Detailed descriptive statistics are presented in Table 4.6.

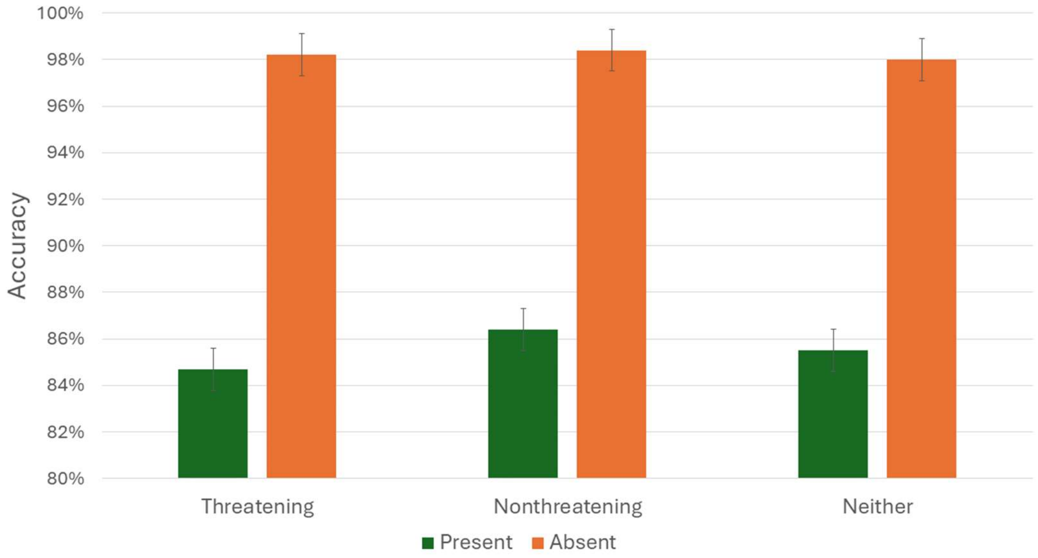

Figure 4.5 – Performance on the task as measured by accuracy of identifying the target. Findings are presented across Target presence (green and orange bars) and Special Distractor Type. Error bars represent one standard error of the mean.

4.3.1.4.2 Reaction Time

The main effect of Presence of the Target was significant. As shown on Figure 4.6, participants were slower in target-absent compared to target-present trials. The main effect of Type of Special Distractor was nonsignificant.

The interaction between Presence of the Target and Type of Special Distractor was significant (see Figure 4.6). On *target-present* trials, we found a nonsignificant trend regarding Type of Special Distractor, indicating that participants were slower when a threatening distractor was present compared to trials with a nonthreatening but visually similar distractor. However, the difference between the threatening distractor and no special distractors present conditions, and the two neutral conditions did not differ from each other. On *target-absent* trials, the Type of Special Distractor main effect was nonsignificant. See Table 4.3 for all statistical results. Detailed descriptive statistics are presented in Table 4.6.

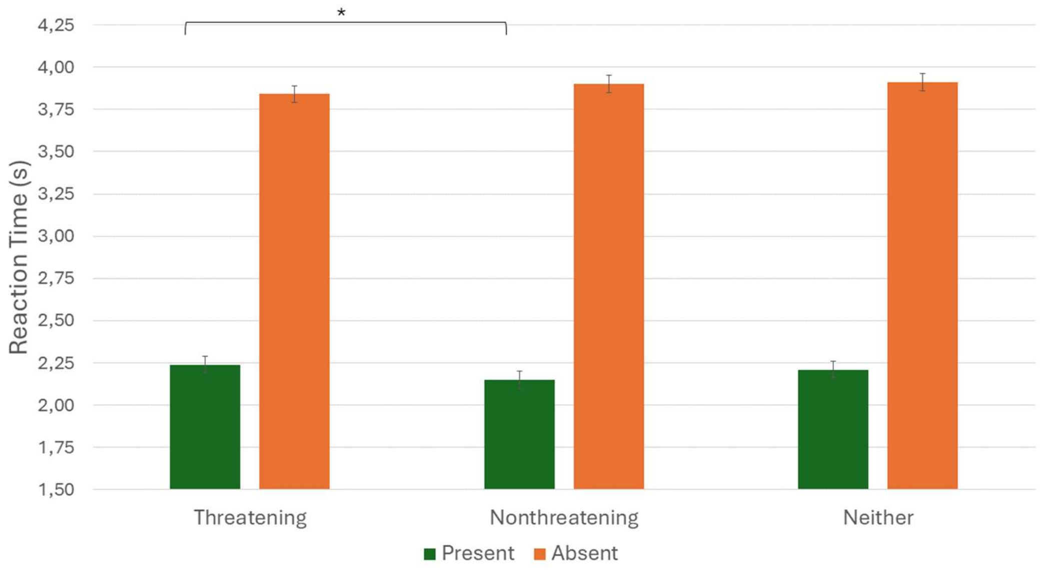

Figure 4.6 – Performance on the task as measured by the reaction time for finding the target (in seconds). Findings are presented across Target presence (green and orange bars) and Special Distractor Type. Error bars represent one standard error of the mean.

Table 4.3 – Detailed statistical results for Experiment 1, Target-Absent and Target-Present trials (accuracy, reaction time) with main effects, interactions, and follow-up simple effects.

Measurement	Effect	df	F/t	p	η^2p
Accuracy	**Presence of Target**	**1,47**	**112.22**	**<0.001**	**0.700**
	Type of Special Distractor	2,94	2.00	0.141	
	Interaction	2,94	1.28	0.282	
Reaction Time	**Presence of Target**	**1,47**	**162.39**	**<0.001**	**0.779**
	Type of Special Distractor	2,94	0.59	0.553	
	Interaction	**2,94**	**4.09**	**0.020**	**0.082**

Measurement	**Effect**		**df**	**F/t**	**p**	**η^2p**
	Target Present Trials					
		Threatening - Nonthreatening	**47**	**2.83**	**0.019**	

4.3.2 Experiment 2

4.3.2.1 Fixation Count on Distractors

We began eye-tracking analysis by examining the fixation count on distractors to test our first prediction that participants would fixate on distractors with affective features more than to visually similar distractors without affective features. See Table 4.4 for all statistical results, and Tables 4.6 and 4.7 for the descriptive statistics. The main effect of Distractor Type was not significant. Our second hypothesis was that this effect would be independent of the distance between the distractor and the target when the distractor had affective features, but that when distractors were emotionally neutral (but visually similar to threats), the effect would decrease as the distance between targets and the distractor increased. The main effect of Distance was significant; participants were more likely to fixate the special distractor when it was close to the target compared to when it was far from it. Figure 4.7 shows the significant interaction between Distractor Type and Distance. Participants were more likely to look at both threatening and nonthreatening distractors when they appeared closer to the target. This effect of distance, however, was greater for nonthreatening compared to threatening distractors. There was no difference between the two types of distractors in the far condition.

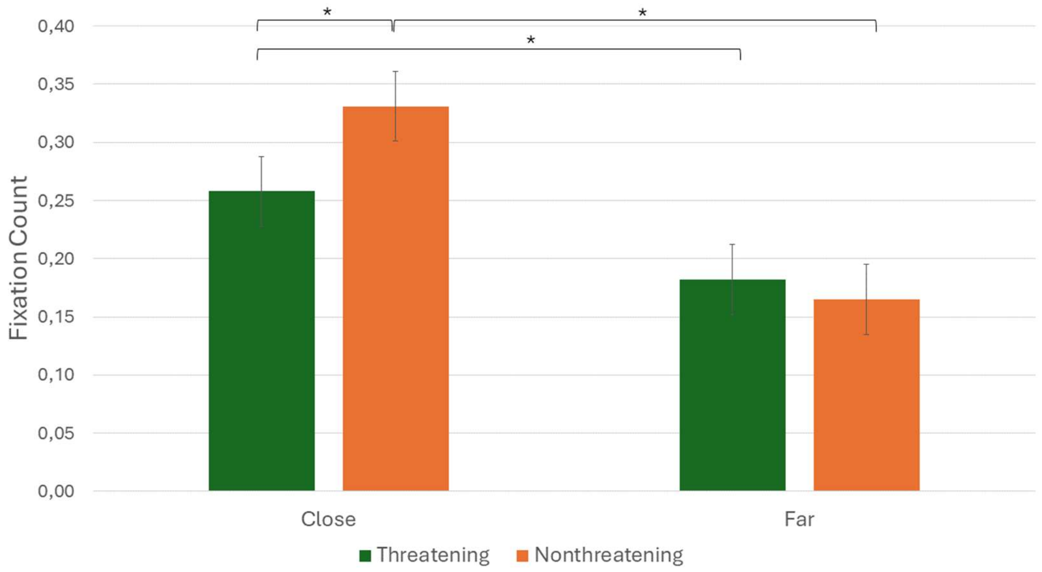

Figure 4.7 – Fixation count on the special (threatening, nonthreatening) distractor. Findings are presented across Distractor Type (green and orange bars) and Distance from the Target. Error bars represent one standard error of the mean.

Table 4.4 – Detailed statistical results for Experiment 2 (fixation count and total fixation time on distractors) with main effects, interactions, and follow-up simple effects.

Measurement	Effect	df	F/t	p	η²p
Fixation count	Distractor Type	1,23	1.6	0.218	0.065
	Distance	**1,23**	**29.17**	**< .001**	**0.559**
	Interaction	**1,23**	**5.84**	**0.024**	**0.202**
	Simple main effects				
	Threatening Close – Threatening Far	**23**	**2.785**	**0.011**	
	Threatening Close – Nonthreatening Close	**23**	**-2.696**	**0.013**	
	Threatening Far – Nonthreatening Far	23	0.455	0.654	
	Nonthreatening Close – Nonthreatening Far	**23**	**5.451**	**< .001**	
Total fixation time	**Distractor Type**	**1,22**	**8.42**	**0.008**	**0.277**
	Distance	1,22	3.59	0.071	0.140
	Interaction	1,22	1.92	0.180	0.080

4.3.2.2 Total Fixation Time on Distractor

We next examined total fixation time on distractors to test our first prediction that participants would look longer at distractors with affective features than at visually similar distractors without affective features. The main effect of Distractor Type was significant. As displayed in Figure 4.8, participants fixated nonthreatening distractors longer compared to threatening ones. Our second hypothesis was that this effect will be independent of the distance between the distractor and the target when the distractor had affective features, but that when distractors were emotionally neutral (but visually similar to threats), the effect would decrease as the distance between targets and the distractor increased. The main effect of Distance and the interaction between Distractor Type and Distance were not significant.

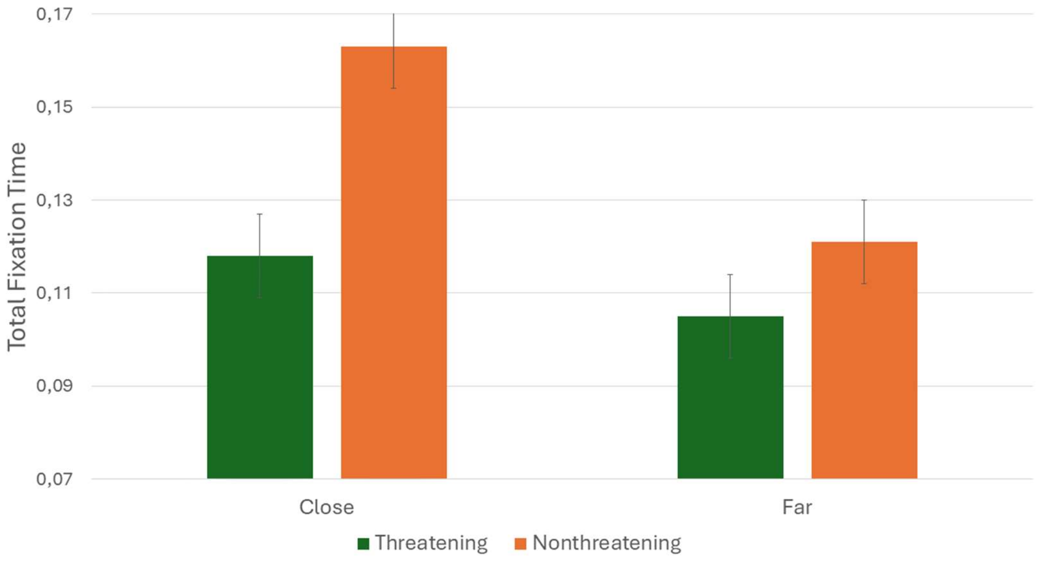

Figure 4.8 – Total fixation times on the special (threatening, nonthreatening) distractors. Findings are presented across Distractor Type (green and orange bars) and Distance from the Target. Error bars represent one standard error of the mean.

4.3.2.3 Target-Absent vs. Target-Present Trials

We performed 2x2 repeated measures ANOVAs to test the effect of Presence of the Target (present or absent) and Type of Special Distractor (threatening, nonthreatening visually similar, neither) on eye movements (indicated by fixation count and duration). Main effects and interactions are reported separately, paired with relevant follow-up ANOVAs or t-tests to further investigate the significant interactions. Effect sizes are also presented: partial eta squared (η_p^2) for the ANOVAs. Tukey corrections were used to account for multiple comparisons.

4.3.2.3.1 Fixation Count

The main effect of Presence of the Target was significant. As shown on Figure 4.9, participants fixated on special distractors more in target-present compared to target-absent trials. The main effect of Type of Special Distractor was also significant showing that participants fixated more on nonthreatening visually similar distractors compared to threatening ones.

The interaction between Presence of the Target and Type of Special Distractor was significant (see Figure 4.9). On *target-absent* trials, there was no difference in terms of fixation counts between threatening and nonthreatening but visually similar distractors. On *target-present* trials, there was a significant difference. Participants fixated on nonthreatening but visually similar distractors more often than threatening ones. See Table 4.5 for all statistical results. Detailed descriptive statistics are presented in Table 4.6.

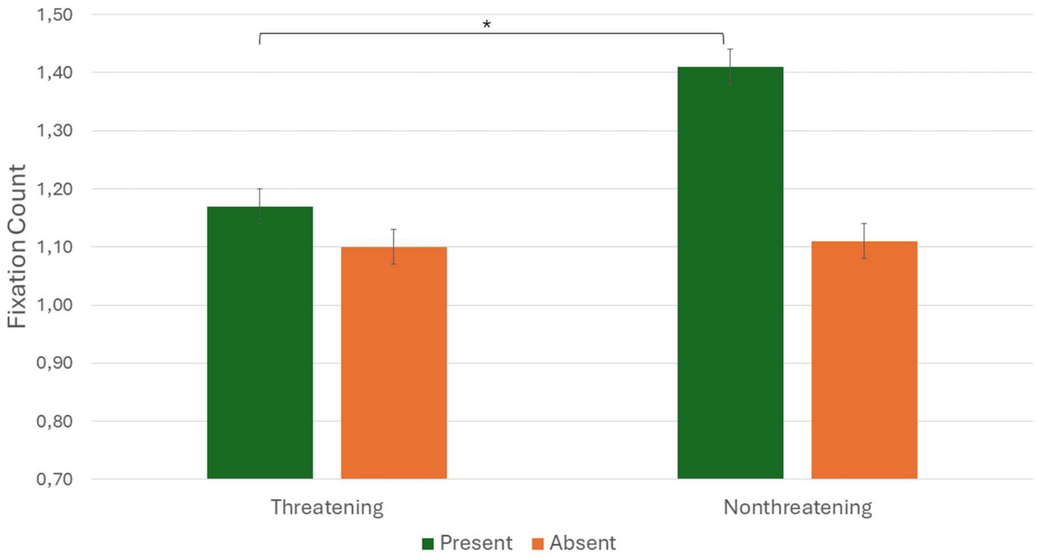

Figure 4.9 – Fixation counts on the special distractors. Findings are presented across Target presence (green and orange bars) and Special Distractor Type. Error bars represent one standard error of the mean.

4.3.2.3.2 Total Fixation Time

The main effect of Presence of the Target was significant. As shown on Figure 4.10, participants fixated on special distractors longer in target-absent compared to target-present trials. The main effect of Type of Special Distractor was nonsignificant.

The interaction between Presence of the Target and Type of Special Distractor was significant (see Figure 4.10). On *target-present* trials, there was a significant difference. Participants fixated on nonthreatening but visually similar distractors longer than threatening ones. On *target-absent* trials, there was no difference in terms of fixation duration between threatening and nonthreatening but visually similar distractors. See Table 4.5 for all statistical results. Detailed descriptive statistics are presented in Table 4.6.

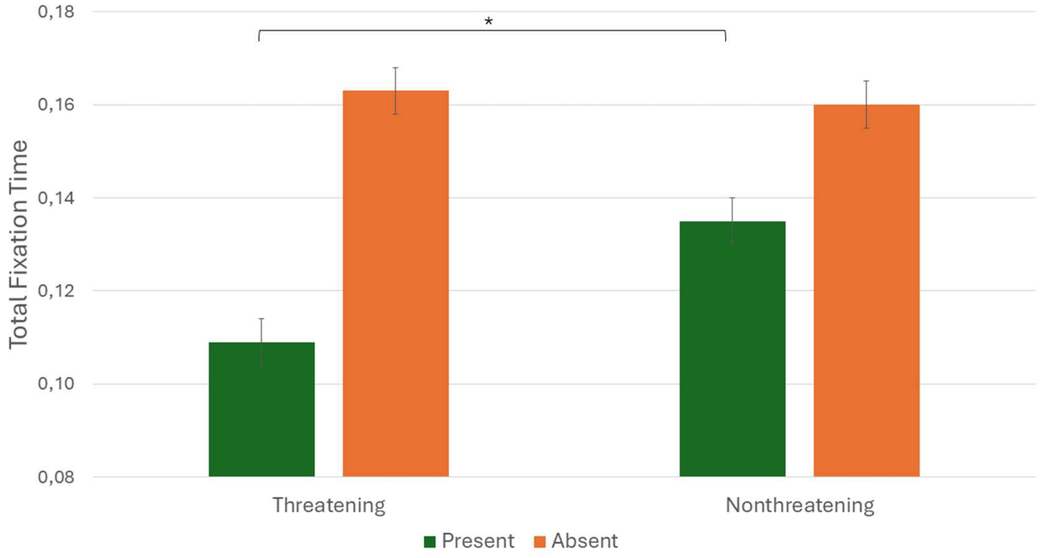

Figure 4.10 – Total fixation time on the special distractors. Findings are presented across Target presence (green and orange bars) and Special Distractor Type. Error bars represent one standard error of the mean.

Table 4.5 – Detailed statistical results for Experiment 2, Target-Absent and-Target Present Trials (fixation count and total fixation time on distractors) with main effects, interactions, and follow-up simple effects.

Measurement	**Effect**		**df**	**F/t**	**p**	**η^2p**
Fixation Count	**Presence of Target**		**1,23**	**10.47**	**0.004**	**0.313**
	Type of Special Distractor		**1,23**	**9.06**	**0.006**	**0.283**
	Interaction		**1,23**	**7.83**	**0.010**	**0.254**
	Target Present Trials					
		Threatening - Nonthreatening	**23**	**3.21**	**0.004**	
Total Fixation Time	**Presence of Target**		**1,23**	**21.32**	**<0.001**	**0.492**
	Type of Special Distractor		1,23	3.59	0.071	
	Interaction		**1,23**	**4.35**	**0.049**	**0.165**
	Target Present Trials					
		Threatening - Nonthreatening	**23**	**2.37**	**0.027**	

Table 4.6 – Descriptive data for performance on the task as measured by reaction time (seconds), accuracy (proportion correct), fixation counts (number) and total fixation times on the special distractors (seconds) presented separately for each condition.

				95% Confidence Interval	
	Target presence	**Distractor type**	**Mean**	**Lower**	**Upper**
Exp1 – RT	Present	Threatening	2.24	2.13	2.34
		Nonthreatening	2.15	2.04	2.26
		Neither	2.21	2.1	2.31
	Absent	Threatening	3.84	3.53	4.15
		Nonthreatening	3.9	3.57	4.23
		Neither	3.91	3.57	4.25
Exp1 – Accuracy	Present	Threatening	0.847	0.818	0.875
		Nonthreatening	0.864	0.841	0.888
		Neither	0.855	0.824	0.886
	Absent	Threatening	0.982	0.973	0.991
		Nonthreatening	0.984	0.975	0.993
		Neither	0.98	0.969	0.991
Exp1 -BIS	Present	Threatening	0.1007	-0.2002	0.4015
		Neither	0.2692	0.0297	0.5087
	Absent	Threatening	-0.4708	-0.7838	-0.1577
		Nonthreatening	-0.393	-0.69	-0.096
		Neither	-0.3992	-0.7088	-0.0896
Exp2 -Fixation count	Present	Threatening	1.17	1.04	1.29
		Nonthreatening	1.41	1.28	1.53
	Absent	Threatening	1.1	1.05	1.16
		Nonthreatening	1.11	1.06	1.16
Exp2 -Fixation duration	Present	Threatening	0.109	0.0906	0.128
		Nonthreatening	0.135	0.1145	0.155
	Absent	Threatening	0.163	0.1489	0.177
		Nonthreatening	0.16	0.1512	0.168

Table 4.7 – A table of descriptive data for performance on the task as measured by accuracy (proportion correct), reaction time (seconds), Balanced Integration Score (BIS), fixation count and total fixation times on the special distractors (seconds) presented separately for each condition.

						95% Confidence Interval	
	Measurement	**Distractor type**	**Distance from target**	**Mean**	**SE**	**Lower**	**Upper**
Experiment 1	**Accuracy**	Threatening	Close	0.843	0.0161	0.811	0.876
			Far	0.848	0.0149	0.818	0.878
		Nonthreatening	Close	0.819	0.016	0.787	0.851
			Far	0.887	0.0126	0.862	0.912
	Reaction time	Threatening	Close	2.22	0.0505	2.12	2.33
			Far	2.28	0.0646	2.15	2.41
		Nonthreatening	Close	2.22	0.0602	2.1	2.34
			Far	2.13	0.0606	2.01	2.25
	BIS	Threatening	Close	-0.00773	0.166	-0.341	0.325
			Far	0.04093	0.147	-0.254	0.336
		Nonthreatening	Close	-0.18837	0.16	-0.511	0.134
			Far	0.51263	0.131	0.25	0.776
Experiment 2	**Fixation count**	Threatening	Close	0.258	0.0297	0.196	0.319
			Far	0.182	0.0194	0.142	0.222
		Nonthreatening	Close	0.331	0.033	0.262	0.400
			Far	0.165	0.0206	0.123	0.208
	Total fixation time	Threatening	Close	0.118	0.01376	0.0897	0.147
			Far	0.105	0.01276	0.0781	0.131
		Nonthreatening	Close	0.163	0.00762	0.1467	0.178
			Far	0.121	0.01365	0.0927	0.149

The results contradict our first hypothesis because participants were more likely to fixate and looked longer at nonthreatening compared to threatening distractors. Further, we could not confirm our second hypothesis either as both fixation count and time decreased when special distractors were presented far compared to close to the target, and there was no difference between the two types of special distractors in the far condition.

4.4. Discussion

A large body of prior research (Becker et al., 2011; Blanchette, 2006; Coelho et al., 2019; Csathó et al., 2008; LoBue, 2010; March et al., 2017; Subra et al., 2017; Williams et al., 2006; Zsido, Csatho, et al., 2019; Zsido, Deak, et al., 2019) has shown that threatening stimuli are highly salient, and thus, tend to be detected faster and more efficiently than neutral objects or those that elicit different emotions. Current theories (Coelho & Purkis, 2009; Davey, 1995; LoBue, 2014; Mather & Sutherland, 2011; Zsido et al., 2018) seem to disagree on whether this advantage is caused by the visual or emotional features of the objects. The result of more recent studies (Burra et al., 2019; Sawaki & Luck, 2010; Zsido et al., 2021) suggests that investigating the efficiency of inhibition could help resolve the debate. Thus, in the present study, we used task-irrelevant distractors that were either threatening or nonthreatening but visually similar to threats (and these items were placed near or far from the target of search). The goal of our study was to test how these salient but task-irrelevant stimuli capture attention in a visual search task, and to explore whether the affective or visual features of the stimuli were more influential in the biasing of attention. While we are interested in visual features generally, the present research is just the first step of discovering their potential effects. There are a number of variables that would fit the category of visual features such as pose, skin texture, fangs/teeth, colour. Thus, our findings here can really only be directly applied to the shape feature.

Based on behavioural measures, we found that threatening distractors interfered with the task more compared to nonthreatening ones, and that the influence of threats impacted task performance regardless of their proximity to the search target. By contrast, nonthreatening items were examined for longer (which may be taken as evidence that they were not suppressed) but only affected performance when they appeared close to the target. In sum, these results may indicate that the suppression of neutral stimuli was not necessary because they did not interfere with the task, while threatening stimuli interfered with task performance due to an increase in cognitive load as participants actively inhibited it during the trial. When the special distractor appeared close to the target (compared to being positioned further away), we found no difference between threatening and nonthreatening distractors regarding accuracy, RTs, and BIS. Thus, the affective and visual features of threats similarly influenced task performance and distracted participants from the task. This may allow us to draw the following conclusions: (1) threatening information does provide an attentional advantage (Blanchette, 2006; March et al., 2017; Öhman & Mineka, 2001; Subra et al., 2017; Williams et al., 2006; Zsido et al., 2018, 2021), one so strong that when presented near to foveation of the target, inhibiting such information without behavioural consequences may not be possible; and (2) threatening information can be ascertained very quickly, with minimal stimulus detail available to foveal vision – in this case, shape similarity was enough to elicit interference.

In previous studies, this latter phenomenon was tested with simple geometric shapes. Downward pointing V stimuli that can be associated with snake heads are reacted to faster and elicit activation in the amygdala (Larson et al., 2007, 2009; Van Strien et al., 2016), and curvilinear shapes and lines are detected faster compared to straight and zigzag lines (LoBue et al., 2014). Thus, shapes that signal threat (in the same way as affective features do) potentially create an automatic “attend-to-me” signal that is difficult to inhibit, which results in decreased performance (longer RT, lower accuracy) for both threatening and visually similar nonthreatening distractors. However, here we also found that participants fixated on nonthreatening distractors for a longer duration of time. This might indicate that nonthreatening (distractor) objects were ambiguous. They may have created the “attend-to-me signal” (automatically attracting attention) but when participants examined them (i.e., fixated on the distractor), they then realised that no threat was present. Such ambiguity may prompt closer inspection of the object, resulting in more time spent looking at the item. Because the fixation count was also higher for nonthreatening distractors in the close condition, it is not likely that the longer looking time was due to a delayed disengagement (Sawaki & Luck, 2010, 2011). Rather the ambiguity of the stimuli seems to have prompted a higher number of fixations, accumulating in longer total viewing times.

While both threatening and nonthreatening distractors decreased performance on the behavioural task when presented closer to the target, only threatening (but not nonthreatening ones) did so when presented far from the target. However, the total fixation duration was lower for threatening compared to nonthreatening distractors. In previous studies (Bayle et al., 2009; Hung et al., 2010), peripheral stimulus presentation resulted in a quicker neural activation (measured by MEG) as opposed to foveal presentation in emotional, compared to neutral, stimuli. Indeed, threatening stimuli have been shown (Calvo & Lang, 2005; Csathó et al., 2008; Liddell et al., 2005; Wang et al., 2018) to have prioritised access to visual processing via the brainstem–amygdala–cortex alarm system, which plays a vital role in the quick detection of threatening stimuli in the periphery. This system ensures that the automatic alert response to threatening stimuli is also present for threatening stimuli that fall outside of the centre of attention (Bayle et al., 2009; Hung et al., 2010; Rigoulot et al., 2011, 2012). Previous studies proposed that the processing of the visual features strongly associated with threats (such as a sinusoidal shape) does not suffer from declining performance in the peripheral visual field (compared to foveal visual processing (Carretié et al., 2017; De Cesarei & Codispoti, 2008; Gao et al., 2017). Such information may trigger the brainstem–amygdala–cortex alarm system, drawing the focus of attention, and thereby resulting in a quick orientation to the stimulus. However, our results are in line with a previous fMRI study (Almeida et al., 2015) showing that the amygdala activation was only observed for true snake pictures and not for fake ones (the stimulus was snake shaped but not a real snake) when presented in the periphery. This might be because both this and our study presented threatening and visually similar nonthreatening stimuli in the same experiment, while previous studies used only one stimulus type per participant. It seems that visual features can be more easily inhibited in the periphery compared to affective features (Burra et al., 2019). Hence, when the stimulus is actually a threatening item, it causes a greater behavioural interference.

Our results showed that performance (indicated by accuracy, RTs, and BIS) decreased for threatening, relative to nonthreatening, stimuli regardless of the distance between target and distractor. The pairwise comparisons of the behavioural measures indicated that the difference between threatening close and threatening far conditions was nonsignificant; similarly, the difference between threatening close and nonthreatening close conditions were nonsignificant. In contrast, performance improved when the nonthreatening distractor appeared far from the target compared to nonthreatening distractor close to the target and threatening distractor far from the target. When the stimulus was nonthreatening, active suppression of it possibly required fewer resources compared to a threatening stimulus (Bradley et al., 2007; Schupp et al., 2006). This might explain the fact that such distractors interfered less with the completion of the main task. Further, presumably participants fixated on these items for a longer period of time because their spatial positions were not under active inhibition. On the other hand, shape similarity might be an ambiguous source of information before one observes the stimulus to evaluate it, so the higher oculomotor capture and longer fixation times may be a result of an automatic reorientation for reassurance (Calvo & Lang, 2005).

Nevertheless, in our study, we only found evidence of prioritised access to visual processing (i.e., production of behavioural interference) when threatening information came from affective valence, not visual features alone. However, in the distractor absent-present analysis (presented in Supplementary material 2) the main effect of Distractor type was nonsignificant. While this comparison showed no difference between trials with nonthreatening but visually similar to threatening distractors and trials without special distractors, the difference was only evident between threatening and nonthreatening but visually similar trials (not between trials with threatening distractors and trials without special distractors). Thus, these findings are not yet conclusive, and as our study was not designed to be powered for such a comparison, further studies will be needed to clarify the current findings. In sum, it seems that visual features which signal threat are easier to inhibit than actual affective valence when shown outside of central vision.

Although our findings are novel, we should acknowledge certain limitations in the current investigation. First, participants conducted a free visual search, and the foveal position of the special distractors were therefore not fixed. Consequently, we can only interpret our findings in light of their relative distance from the target. Second, the task design preclude us from conducting a more fine-grained analysis of the eye movements such as the destination of the first saccade on a trial as past studies have examined (Gaspelin et al., 2017; Hamblin-Frohman et al., 2022) However, those studies used a small number of objects (4 or 6) with stimuli presented equidistant from fixation while the visual display in the present study was more complex (with 32 objects per trial) and the distance between target and distractors greatly varied. Third, we used eye-tracking methodology[7] which is only capable of recording overt eye-movements. Future experiments should employ other methodologies (such as EEG or MEG) to more fully understand the processes of inhibition during covert attention. Thus, we encourage conceptual replication of our work using other techniques. Finally, in the present investigation we focused on directly comparing two types of distractors (threatening and visually similar nonthreatening). Adding new conditions (e.g. dissimilar nonthreatening and emotional categories other than threat) would be interesting for future research and would probably improve the generalizability of the results.

Taken together, our findings suggest that the inhibition of affective features of threatening information is not (or is only partially) possible regardless of whether such an item appears inside or outside of attentional focus. Threatening stimuli induced behavioural interference, but participants fixated on them less often. This possibly suggests that their spatial position was actively suppressed, diverting cognitive resources away from the main task. In contrast, visual features of threat only interfered with the main task when appearing closer to the focus of attention. Outside of it, the visual features seem to be inhibited more easily but produce more orienting eye-movements (compared to affective features) presumably because they were quickly dismissed as nonthreatening, and their spatial position was therefore not inhibited.

---

[7] One limitation here is that we were unable to verify replication of the RTs due to a mishap with data collection.

5. THE ROLE OF DISGUST IN THE INHIBITION OF TASK-IRRELEVANT STIMULI

5.1 Introduction

Disgust has been recognized as a fundamental emotion, as observed by Darwin in 1872 (Darwin, 1965). It becomes apparent even in neonates in the form of distaste, and it later becomes associated with avoiding disease and experiencing intense repulsion towards biological and psychological contamination and violation. Much like fear, disgust serves as a central emotion related to threats in the field of psychopathology and phobias (Vernon & Berenbaum, 2002, Kiss et al., 2022, Birkás et al., 2023). However, many of differences prevail between these emotions. On a physiological level, disgust tends to trigger parasympathetic responses, leading to the reduction of heart rate, blood pressure, and respiration rate, thereby inhibiting immediate action. In contrast, fear activates sympathetic pathways, raising heart rate, blood pressure and respiration, prompting a fight or flight response (Charash, McKay & Dipaolo, 2006; Krusemark & Li, 2011; Van Hooff et al., 2013). Furthermore, fearful expressions broaden the field of vision, accelerate eye movements, and heighten nasal volume and airflow, while expressions of disgust produce opposing effects (Vermeulen, Godefroid & Mermillod, 2009). Differences between these emotions were also observed on a cognitive level: those motivated by fear tend to be vigilant, seeking to gather as much information as possible about the frightening stimulus. In contrast, individuals motivated by disgust are inclined to shield themselves from the unpleasant, revolting stimulus (Vernon & Berenbaum, 2002; Charash, McKay & Dipaolo, 2006).

A growing body of evidence from psychological, psychophysiological, neurobiological, and cognitive studies suggests that the emotion of disgust, associated with the diseases, is a prominent emotion in various psychopathologies. The disease avoidance hypothesis (Matchett & Davey, 1991; Davey, 1994a/1994b) emphasises the idea that disgust has evolved as a mechanism to protect individuals from the potential threat of disease and contamination. In their initial study, Matchett and Davey (1991) discovered a direct correlation between disgust sensitivity and contamination fear with elevated levels of animal phobia and fear related to illness and death. According to their findings, the emotion of disgust was particularly linked to animals that would not physically attack humans but are associated with dirt, decay, or disease (e.g. rats, spiders, worms, snails, and cockroaches). Interestingly, disgust showed a lesser association with larger predatory species capable of causing harm or injury to humans, such as tigers, lions, sharks, crocodiles, and bears, which more commonly evoke fear. The nature of the threat posed by animals appears to determine whether they elicit feelings of fear, disgust, or a combination of both (Coelho et al., 2023). It is no wonder that disgust shows significant associations with specific phobias, such as small animal phobias (particularly arachnophobia), blood–injection–injury phobia, and contamination fears in obsessive–compulsive disorder. These disorders share primary disgust elicitors as a substantial component of their pathomechanism. Interestingly, however, in many mental health issues lacking the disease-avoidance functionality characteristic, disgust still represents a significant vulnerability factor for them (e.g. agoraphobia, claustrophobia, eating disorders) (Davey, 2011).

That said, even though both fear and disgust are considered negative affects, the key physiological and cognitive differences may result in different attention biases towards stimuli that evoke these emotions. Among the studies that have undertaken this comparison, they discovered more pronounced biases towards stimuli evoking disgust than neutral stimuli or stimuli evoking fear (Charash, McKay & Dipaolo, 2006, Carretié, et al., 2011; Chapman et al., 2013; Van Hooff et al. 2013; Fink-Lamotte, 2022) or even happiness (Van Hooff et al., 2014). Carretié et al. (2011) recorded event-related potentials and behavioural measures during a digit categorization task, where participants had to indicate if the central numbers on the screen are even or odd numbers. The participants were placed in three groups, each exposed to a type of distracting picture during the task: disgusting, fearful, and neutral. Findings indicated that performance on digit categorization was poorer in response to disgust-inducing trials compared to fear-inducing trials, evidenced by increased reaction times and number of errors. Additionally, the activation of the P2-associated cuneus and anterior P2 amplitude on the scalp was greater for disgusting distractors than for fearful ones. These results collectively suggest that, in the study's experimental conditions, disgusting distractors were more effective in capturing exogenous attention than fearful distractors. Another study (Van Hooff et al., 2013) investigated attention bias effects related to attention (dis)engagement in response to fear- and disgust-evoking images. Participants were instructed to identify briefly presented targets (letters Z and N) around central image cues (which could be threatening, disgusting, or neutral), with varying intervals between cue onset and target presentation (200, 500, 800, 1100ms). Notably, quicker target presentation (200ms onset) following disgust-evoking images resulted in lower accuracy and longer reaction times compared to neutral- or fear-evoking images. No significant differences were observed for the longer onset target presentations. Another study by Van Hoof et al. (2014) used the same methodology as previously described but included happiness evoking pictures in the array of distractors and an even shorter target presentation onset (100, 200, 500, or 800ms). In this experiment, half of the participants were asked to pay close attention to the distractor pictures for a recognition task later (attend condition), while the other half of the participants were given no such instruction (ignore condition). Results revealed that reaction times were delayed for targets following disgust-evoking pictures at 100 and 200ms intervals, indicating a temporary capture of attention by these images. This effect was consistent across ignore- and attend-instructions, unaffected by anxiety levels or disgust sensitivity, suggesting a robust influence on early attention processes. In contrast, a less reliable effect of delayed responding was observed for all emotional pictures in the 100ms interval, particularly in participants with higher state-anxiety scores. The reason behind this might be the costs and benefits of exploration, as suggested by Carretié et al. (2011). Despite the repulsive nature of disgust, it does not entail a biological cost associated with exploration. Instead, there are potential benefits to consider: the object of our revulsion might turn out not to be dangerous to our health or integrity once examined. Therefore, the most advantageous response in such cases would be to investigate the disgusting event in order to determine whether it poses an actual threat or could potentially be safe, rather than hastily fleeing from it. On the contrary, allocating excessive cognitive resources to the processing of threatening and fear-inducing events – such as predators or attackers – rather than avoidance or defence, would result in more costs than benefits. Thus, disgusting distractors are more likely to be objects of further exploration compared to fearful distractors (Carretié et al., 2011).

It is also important to consider that previous experiments investigating attention toward scenes evoking fear may have involved elements of disgust. This is particularly relevant considering some of the classic fear-inducing stimuli – like certain animals such as spiders or snakes (Polák et al., 2020), or scenes depicting physical injury – which can also elicit feelings of disgust (Carretié et al., 2011). It has been demonstrated that disgust is a more reliable predictor than fear when it comes to avoiding spiders (Woody, McLean & Klassen, 2005), and it holds an even stronger predictive role in cases of fear related to blood, injections, or injuries (Kiss et al., 2022, Birkás et al., 2023). A few studies, adopting behavioural assessment methods, have delved into the role of disgust in fearful avoidance. In line with the disease avoidance model of disgust, Mulkens and colleagues (1996) conducted an experiment in which female participants were invited to eat a cookie walked across by a spider. Results revealed that 71% of nonphobic women consumed the cookie, contrasting with only 25% of phobic women. Similar findings were reported by de Jong and Muris (2002) in a questionnaire study involving spider-phobic girls aged 10–14. They indicated a reduced eagerness to consume their favourite candy bar if a spider had walked across it, even when the bar was packaged. Non-phobic girls also displayed reduced enthusiasm for a spider-touched chocolate bar, though to a significantly lesser extent (Woody, McLean & Klassen, 2005). Consequently, when we extract the components of disgust from stimuli typically categorised as fearful, they may lose a portion of their innate ability to automatically capture our attention (Carretié et al., 2011).

Much like the scarcity of research on fear inhibition, our understanding of inhibitory mechanisms in response to disgusting stimuli also lacks in-depth exploration. An ERP study (Xu et al., 2015) aimed to explore the impact of fearful and disgusting distractors on inhibitory control, both at a conscious and unconscious level. They utilised a masked Go/No-Go task set against emotional backgrounds of fear, disgust, or neutrality, while event-related potentials were measured. The findings revealed that in both conscious and unconscious (masked) conditions, disgusting stimuli evoked a larger P2 (positive potential, occurring within the 180 to 350ms time frame, situated over the centro-parietal and parieto-occipital regions, increases in amplitude when a negative stimulus automatically captures attention) response compared to fearful stimuli. Additionally, the difference in P3 (an index of inhibitory capability, in which larger P3 difference waves indicate a more robust ability to inhibit or suppress the prepotent response) amplitude between disgusting and fearful contexts was smaller. These results suggest that disgusting distractors demand more attentional resources, consequently impairing subsequent inhibitory control to a greater extent than fearful distractors (Xu et al., 2015). Another study (Xu et al., 2016) found that fearful distractors enhanced reactive inhibition in comparison to both disgusting and neutral distractors. The aim of the study was to explore whether fearful and disgusting distractors yield distinct effects on proactive and reactive inhibition. Proactive inhibition is goal-oriented, involving predictive cues, and requires sustained attention to prepare for optimised behaviour. Reactive inhibition, on the other hand, is stimulus-driven, triggered by salient signals, and focuses on halting actions swiftly. In the experiment, participants were instructed to perform a modified stop-signal task while exposed to fearful, disgusting, or neutral image cues. When it came to inhibition, fearful distractors improved reactive inhibition more effectively than both disgusting and neutral distractors. On the other hand, disgusting distractors were better at enhancing proactive inhibition when compared to fearful distractors. Additionally, there was a positive correlation between reactive and proactive inhibition across all contexts, including fearful, disgusting, and neutral scenarios (Xu et al., 2016).

In this study, our goal was to test whether attentional capture by disgusting stimuli could be inhibited. Further, we sought to test whether the distance between a distractor and the target has any effect on attentional orientation or inhibition. Considering previous critique, we conducted this new experiment to determine whether the fearful and shape-similar distractors (snakes and worms) used in Study II could have elicited feelings of disgust instead of fear, by using disgusting distractor images (cockroaches) in this study. We expected greater attentional capture effects of disgusting distractors compared to neutral ones, regardless of the distractor's distance from the target. We also expected to see worse task performance when disgusting distractors were presented, compared to threatening and nonthreatening distractors presented in Study II, due to the physiological-response differences between the emotions. We expected participants to be slower to find the target when disgusting distractors were presented to them compared to other distractors, as well as having worse accuracy on the task, on account of difficulty of inhibiting disgusting distractors and difficulty of disengaging from them. Disgust typically induces parasympathetic responses, resulting in decreased heart rate, blood pressure, and respiration, inhibiting immediate action. On the other hand, fear triggers sympathetic pathways, elevating heart rate, blood pressure, and respiration, prompting a fight-or-flight response (Charash, McKay & Dipaolo, 2006; Krusemark & Li, 2011; Van Hooff et al., 2013). In addition, threatening stimuli have been proved to trigger the arousal stimulation effect, which increases task performance (Zsidó et al., 2018; 2022; 2023).

5.2 Method

This experiment was an extension of our previous study (Study II), where the special distractors, *threatening* and *nonthreatening*, were replaced by *disgusting* (roaches) and *neutral* (rabbits) categories. In this experiment we employed the same visual search task as in Study I, based on a previously published experiment (Hout et al., 2015). Participants were tasked with identifying a neutral target from a category, such as a lock or butterfly, amidst an array of pictures depicting everyday objects like a ball, doll, or flower. In half of the trials, one of the distractors was a "special distractor" belonging to either a category associated with negative but nonthreatening emotion (disgust, e.g., roaches) or a category that was devoid of any negative connotations (e.g., rabbit). For the sake of clarity, we will refer to the latter category as neutral distractors. It is important to note that participants were unaware of this manipulation. Additionally, we varied the proximity between the target and the special distractor, presenting it either near or far from the target's location.

5.2.1 Participants

The required sample size was determined based on the results (i.e., interaction effects of Study I., Experiment 1). The analysis indicated that the minimum required total sample size was 12. A total of 23 students participated (mean age = 26.5, SD = 4.52) in this study. These students received course credit for participation.

All participants were right-handed and reported having normal or corrected-to-normal vision as well as normal colour vision. Participants were recruited through university mailing lists and received course credit for their participation. Data was collected in Germany, at designated laboratories in the building of the Institute of Psychology, University of Hildesheim. Our research received approval from the United Ethical Review Committee for Research in Psychology of Hungary and was conducted in strict accordance with the ethical guidelines outlined in the Code of Ethics of the World Medical Association (Declaration of Helsinki). All participants provided written informed consent prior to their involvement in the study.

5.2.2 Experimental Stimuli and Designs

We used the exact same stimuli set as in Study II with only one manipulation, that is, we switched the threatening and nonthreatening special distractors with disgusting and neutral categories. The disgusting category consisted of images of roaches, while the neutral category consisted of images of rabbits, all collected from the Internet (64 images all in all, 32 – disgusting and 32 – neutral).

5.2.3 Procedure

The procedure of the experiment was the same as that of Study II, except that data collection took place individually. The sessions were conducted in a quiet room. Each participant was seated approximately 60 cm in front of a 15.6-inch LCD monitor. The monitor featured a resolution of 1920x1080, a 16:9 aspect ratio, a refresh rate of 60 Hz, and a colour depth of 16.7 million colours. A research assistant oversaw the experimental sessions.

5.2.4 Statistical Analysis

Statistical analyses were conducted using JAMOVI Statistics Program v2.0 (Jamovi Project, 2018). We examined both reaction time (RT), accuracy, and BIS.

To ensure the robustness of our analyses, we initially identified and excluded outlier trials, defined as those exceeding ±2 standard deviations from the group mean, for each trial and participant. This process led to the removal of less than 1% of all collected data.

Subsequently, we assessed the distribution of the variables to confirm that they did not significantly deviate from a normal distribution (Shapiro-Wilk p-values $> .05$). Following this, we conducted 2x2 repeated measures ANOVAs to investigate the effects of Distractor Type (disgusting, neutral) and Distance from the Target (close, far) on task performance (separately for RT, accuracy, and BIS). Tukey corrections were used to account for multiple comparisons. For the sake of clarity, we will present the statistical results in tables, as it enables a more straightforward comprehension of the findings.

We also performed 2x3 repeated measures ANOVAs to test the effect of Presence of the Target (present or absent) and Type of Special Distractor (disgusting, neutral, neither) on performance (indicated by RTs and accuracy). Main effects and interactions are reported separately, paired with relevant follow-up ANOVAs or t-tests to further investigate the significant interactions. Effect sizes are also presented: partial eta squared (η_p^2) for the ANOVAs. Tukey corrections were used to account for multiple comparisons.

In the process of analysing the data, the possibility of combining the results from Study II and III was considered for a comparative analysis. However, due to several crucial factors, this approach was deemed inappropriate. This decision was based on differences in the distractors, sample sizes, and possible subtle variations in study design. Combining these datasets could introduce confounding factors and compromise the reliability of the analysis.

5.3 Results

5.3.1 Accuracy

Our initial examination focused on accuracy in order to test our prediction regarding the interference of disgusting distractors on task performance compared to neutral distractors. The results are detailed in Table 5.1. The main effect of Distractor Type was significant, indicating that the presence of affective features in distractors significantly impacted accuracy. The presence of disgusting distractors caused worse accuracy on the task than the presence of neutral distractors.

Our second hypothesis posited that the effect of Distractor Type would be independent of the distance between the distractor and the target when the distractor possessed affective features. We anticipated that in cases where distractors were emotionally neutral, the effect would diminish. In this regard, the main effect of Distance produced significance, revealing that participants exhibited lower accuracy when a special distractor was in close proximity to the target compared to when it was positioned farther away. Interaction was nonsignificant between Distractor Type and Distance. Figure 5.1 visually represents how accuracy changed across conditions. Distractors in close proximity to the target and disgusting distractors caused greater interference with the task. See Tables 5.2 and 5.3 for descriptive statistics.

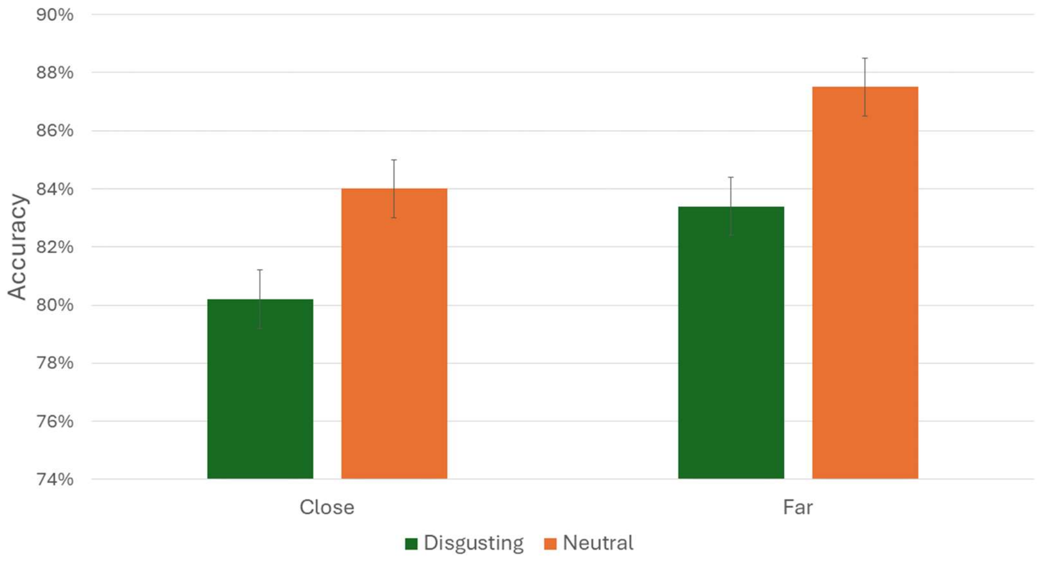

Figure 5.1 – Performance on the task as measured by the accuracy of identifying the target (when a special distractor was present). Findings are presented across Distractor Type (green and orange bars) and Distance from the Target. Error bars represent one standard error of the mean.

Table 5.1 – Detailed statistical results for Study II (accuracy, reaction time, and BIS) with main effects, interactions, and follow-up simple effects.

Measurement	Effect	df	F/t	p	η^2p
Accuracy	**Distractor Type**	**1,22**	**7.703**	**0.011**	**0.259**
	Distance	**1,22**	**4.337**	**0.049**	**0.165**
	Interaction	1,22	0.007	0.933	0.000
Reaction time	Distractor Type	1,22	0.321	0.577	0.014
	Distance	1,22	7.870	0.978	0.000
	Interaction	**1,22**	**4.814**	**0.039**	**0.180**
	Simple main effects				
	Disgusting Close – Disgusting Far	22	-1,289	0.211	
	Disgusting Close – Neutral Close	22	-0.771	0.449	
	Disgusting Far – Neutral Far	**22**	**2.175**	**0.041**	
	Neutral Close – Neutral Far	22	1.470	0.156	
BIS	**Distractor Type**	**1,22**	**5.042**	**0.035**	**0.186**
	Distance	1,22	3.139	0.090	0.125
	Interaction	1,22	0.442	0.513	0.020

5.3.2 Reaction Time

We then examined reaction times to test our hypothesis that distractors with affective features would have greater interference on task-performance compared to neutral distractors. See Table 5.1 for all statistical results. The main effect of Distractor Type was not significant. The main effect of Distance was also not significant. Then, we tested our second hypothesis that this effect will be independent of the distance between the distractor and the target when the distractor was disgusting, but that when distractors were emotionally neutral, the effect would decrease as the distance between targets and the distractor increased. The interaction between Distractor Type and Distance was significant. As shown on Figure 5.2, the effect of distance was significant between disgusting and neutral distractors in the far distance condition. See Tables 5.2 and 5.3 for descriptive statistics.

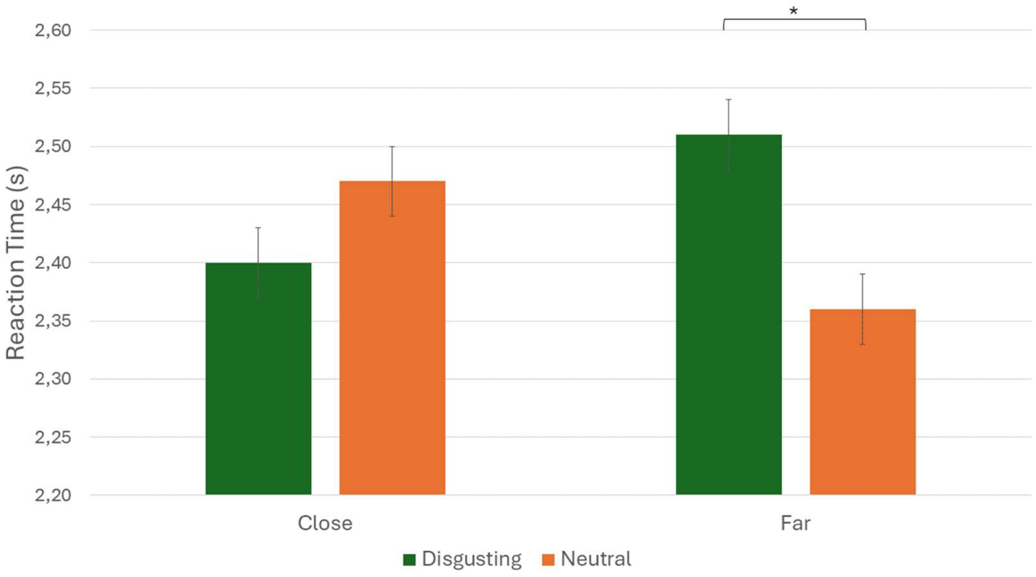

Figure 5.2 – Performance on the task as measured by the RT for finding the target (in seconds) on trials in which a special distractor was present. Findings are presented across Distractor Type (green and orange bars) and Distance from the Target. Error bars represent one standard error of the mean.

5.3.3 Balanced Integration Score

Finally, we analysed BIS to interpret the interplay between accuracy and RT. The main impact of Distractor Type was significant. The main effect of Distance was not significant. The interaction between Distractor Type and Distance was also nonsignificant. As illustrated in Figure 5.3, the impact of Distance lacked significance for disgusting distractors. Neutral distractors were more easily inhibited than disgusting ones. See Tables 5.2 and 5.3 for descriptive statistics.

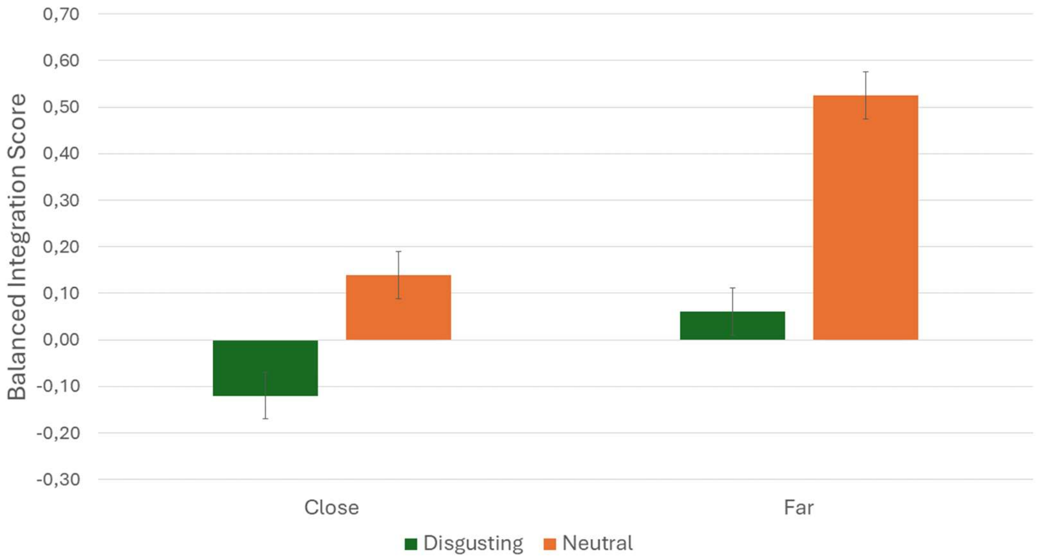

Figure 5.3 – Performance on the task as measured by BIS on trials in which a special distractor was present. Findings are presented across Distractor Type (green and orange bars) and Distance from the Target. Error bars represent one standard error of the mean.

Table 5.2 – Descriptive data for performance on the task as measured by reaction time (seconds) and accuracy (proportion correct) presented separately for each condition.

				95% Confidence Interval	
	Target presence	Distractor type	Mean	Lower	Upper
RT	Present	Disgusting	2.45	2.27	2.64
		Neutral	2.42	2.20	2.63
		Neither	2.4	2.25	2.57
	Absent	Disgusting	4.39	3.94	4.84
		Neutral	4.35	3.88	4.82
		Neither	4.45	3.99	4.92
Accuracy	Present	Disgusting	0.818	0.779	0.857
		Neutral	0.857	0.815	0.9
		Neither	0.844	0.796	0.892
	Absent	Disgusting	0.976	0.943	1.01
		Neutral	0.978	0.951	1.01
		Neither	0.976	0.952	0.999
BIS	Present	Disgusting	-0.0295	-0.368	0.309
		Neutral	0.332	-0.0717	0.735
		Neither	0.228	-0.167	0.622
	Absent	Disgusting	-0.280	-0.672	0.112
		Neutral	-0.222	-0.577	-0.134
		Neither	-0.330	-0.682	0.0209

Table 5.3 – A table of descriptive data for performance on the task as measured by accuracy (proportion correct), reaction time (seconds) and Balanced Integration Score (BIS) presented separately for each condition.

					95% Confidence Interval	
Measurement	Distractor type	Distance from target	Mean	SE	Lower	Upper
Accuracy	Disgusting	Close	0.802	0.0215	0.758	0.846
		Far	0.834	0.0215	0.792	0.876
	Neutral	Close	0.84	0.0291	0.783	0.897
		Far	0.875	0.0205	0.835	0.915
Reaction time	Disgusting	Close	2.4	0.116	2.17	2.63
		Far	2.51	0.0866	2.34	2.68
	Neutral	Close	2.47	0.132	2.21	2.73
		Far	2.36	0.0959	2.17	2.55

					95% Confidence Interval	
Measurement	**Distractor type**	**Distance from target**	**Mean**	**SE**	**Lower**	**Upper**
BIS	Disgusting	Close	-0.120	0.206	-0.523	0.284
		Far	0.0610	0.194	-0.319	0.441
	Neutral	Close	0.139	0.274	-0.399	0.676
		Far	0.525	0.196	0.14	0.91

5.3.1.4 Target-Absent vs. Target-Present Trials

5.3.1.4.1 Accuracy

The main effect of Presence of the Target was significant. As shown on Figure 5.4, participants were more accurate on target-absent compared to target-present trials. The main effect of Type of Special Distractor was marginally significant, people were less accurate when they were presented with disgusting distractors. The interaction between Presence of the Target and Type of Special Distractor was nonsignificant. See detailed statistical results in Table 5.4. Detailed descriptive statistics are presented in Table 5.2.

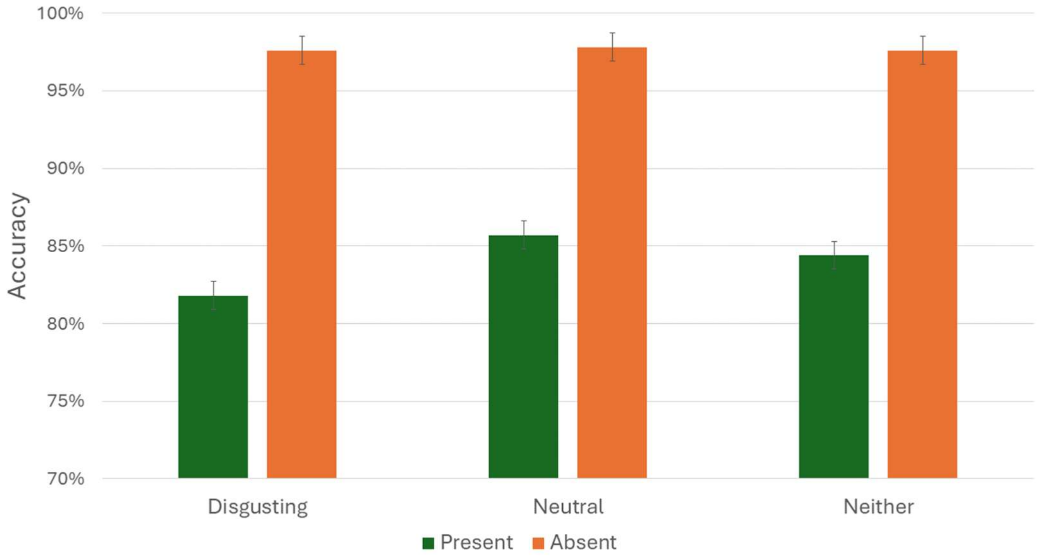

Figure 5.4 – Performance on the task as measured by accuracy of identifying the target (proportion correct values are displayed). Findings are presented across

Target presence (green and orange bars) and Special Distractor Type. Error bars represent one standard error of the mean.

5.3.1.4.2 Reaction Time

The main effect of Presence of the was significant. As shown on Figure 5.5, participants were slower in target-absent compared to target present-trials. The main effect of Type of Special Distractor was nonsignificant. The interaction between Presence of the Target and Type of Special Distractor was nonsignificant. See detailed statistical results in Table 5.4. See Table 5.2 for descriptive statistics.

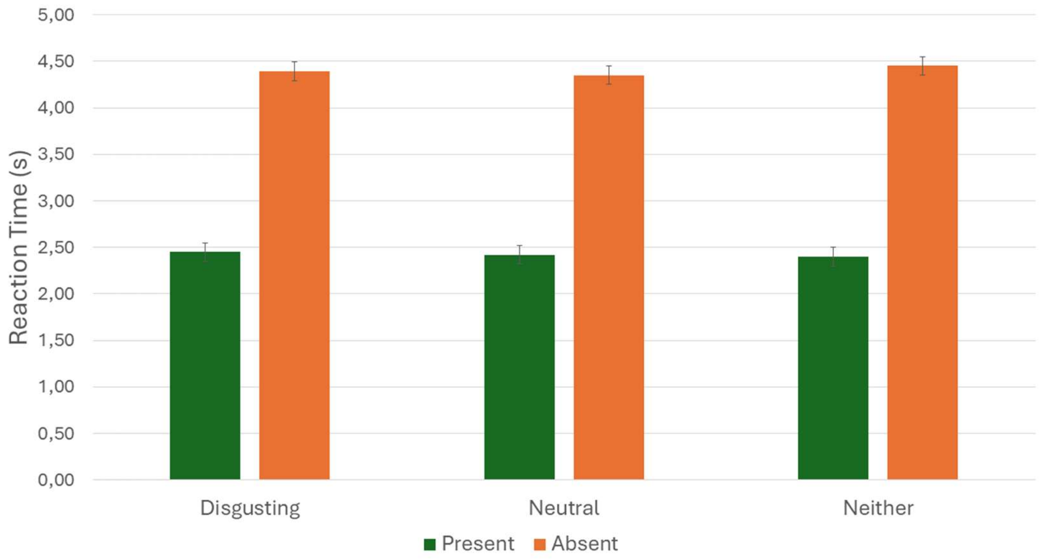

Figure 5.5 – Performance on the task as measured by the reaction time for finding the target (in seconds). Findings are presented across Target presence (green and orange bars) and Special Distractor Type. Error bars represent one standard error of the mean.

Table 5.4 – Detailed statistical results for Target-Absent and Target-Present trials (accuracy, reaction time) with main effects, interactions, and follow-up simple effects.

Measurement	**Effect**	**df**	**F/t**	**p**	**η^2p**
Accuracy	**Presence of Target**	**1,22**	**37.08**	**<0.001**	**0.628**
	Type of Special Distractor	**1,22**	**3.31**	**0.046**	**0.131**
	Interaction	2,44	2.77	0.074	
Reaction Time	**Presence of Target**	**1,22**	**119.64**	**<0.001**	**0.845**
	Type of Special Distractor	2,44	0.59	0.554	
	Interaction	2,44	0.991	0.379	

5.4 Discussion

According to previous research, disgusting stimuli exhibit a more pronounced impact on attentional allocation compared to threatening stimuli (Carretié et al., 2011; Van Hooff et al., 2013; 2014), despite the inherent connection between these two emotions (Woody, McLean & Klassen, 2005; Kiss et al., 2022, Birkás et al., 2023). Several crucial distinctions contribute to the differential reactions of organisms to these emotions. Physiologically, disgust tends to evoke parasympathetic responses, resulting in a decrease in heart rate, blood pressure, and respiration, hindering immediate action. Conversely, fear activates sympathetic pathways, elevating heart rate, blood pressure, and respiration, instigating a fight-or-flight response (Charash, McKay & Dipaolo, 2006; Krusemark & Li, 2011; Van Hooff et al., 2013). Building upon our earlier investigation (Study II), the primary objective of our current study was to explore potential distinctions in attentional inhibition between threatening and disgusting distractors. This curiosity stemmed from the possibility that the stimuli categorised as shape-similar nonthreatening in our previous study might have induced feelings of disgust in participants. To address this, we used the methodology from Study II, maintaining consistency in all aspects, but with a crucial modification: we replaced the threatening distractors with disgusting stimuli and transformed shape-similar nonthreatening distractors into neutral ones.

Analysing the behavioural data – encompassing accuracy, reaction times, and Balanced Integration Score (BIS) measures – we observed, consistent with our hypotheses, that inhibiting disgusting distractors posed greater challenges compared to neutral ones. This pattern was particularly evident in the close distance condition. This suggests that generally, and in line with previous findings (Charash, McKay & Dipaolo, 2006, Carretié, et al., 2011; Chapman et al., 2013; Van Hooff et al. 2013; Fink-Lamotte, 2022), disgusting distractors are harder to inhibit than neutral ones across all distance conditions.

An intriguing aspect for exploration is the comparison between Study II and III across our behavioural measures, encompassing reaction times, accuracy, and BIS. Our findings reveal a distinction between disgusting and neutral distractor types, while less significant differences emerge between threatening and shape-similar distractors. Both experiments indicate that the close condition posed a greater inhibitory challenge compared to the far condition. However, a notable distinction arises when comparing the two studies. In Study II, far threatening and close shape-similar nonthreatening distractors were more challenging to inhibit than far shape-similar nonthreatening ones, suggesting that threatening and disgusting distractors impact task performance similarly, while shape-similar distractors exhibit differences from neutral ones. This finding supports the general feature detection theory (Coelho & Purkis, 2009; Davey, 1995), saying that shape alone can convey threatening information. However, though the initial criticism regarding our shape similar distractors eliciting disgust was refuted, a new question has arisen about whether our threatening distractor also contains components of disgust.

Given the limited distinction observed between threatening and disgusting distractors across our experiments, it is too inconclusive to state that our hypothesis – positing a greater impact of disgusting distractors on performance compared to threatening ones – was supported. It is challenging to definitively proclaim that our threatening distractors (snakes) in Study II did not involve components of disgust, especially considering their comparable impact on behavioural performance to our disgusting distractors (roaches). Previous studies suggest that extracting disgust components from stimuli traditionally categorised as fearful can diminish their inherent ability to automatically capture attention (Carretié et al., 2011). Thus, it appears that these two emotions, fear and disgust, are intricately interconnected, making their separation challenging when using stimuli such as snakes (and spiders (Mulkens, de Jong, & Merckelbach, 1996; Jong & Muris, 2002). The disease avoidance hypothesis (Matchett & Davey, 1991; Davey, 1994a/1994b) underscores the concept that disgust has evolved as a mechanism to safeguard individuals from the potential threat of disease and contamination. In their initial investigation, Matchett and Davey (1991) identified a direct correlation between disgust sensitivity and contamination fear, revealing elevated levels of animal phobia and fear associated with illness and death. In their study, disgust exhibited a weaker association with larger predatory species capable of causing harm or injury to humans, such as tigers, bears, and sharks, which more commonly evoke fear. On the other hand, disgust was specifically associated with animals that are not prone to physically attack humans but are linked to concepts of dirt, decay, or disease. The nature of the threat posed by animals seems to play a role in determining whether they elicit feelings of fear, disgust, or a combination of both (Coelho et al., 2023), and it is very possible that snake distractors would fall into the latter category, evoking a combination of these emotions – just like spider stimuli (Mulkens et al., 1996; Jong & Muris, 2002; Woody, McLean & Klassen, 2005), which are also widely used in the research on threat's impact on attention and perception.

In summary, our findings indicate that inhibiting affective features of disgusting information, just like threatening information, is very difficult, irrespective of whether the item is within or outside the attentional focus. However, we can affirm that shape-similar nonthreatening (worm) and disgusting (roach), as well as neutral (rabbit) distractors exhibited differences across Study II and III, providing evidence in the shape-conveyed information of threat (or the combination of threat and disgust?) rather than presuming that the behavioural results caused by the nonthreatening distractors used in Study II are explained by them evoking disgust only.

6. VISUAL FEATURES DRIVE ATTENTIONAL BIAS FOR THREAT [8]

6.1 Introduction

Threatening stimuli seem to be prioritised in visual perception, resulting in faster detection of threatening objects in the environment (Brown et al., 2010; Fox et al., 2001; Hedger et al., 2016; Öhman & Mineka, 2001; Subra et al., 2017; Zsido, Stecina, et al., 2022). Past studies found that reaction times are significantly faster when it comes to locating threatening target stimuli over neutral ones (Becker et al., 2011; Blanchette, 2006; Brosch & Sharma, 2005; LoBue, 2010; Subra et al., 2017; Williams et al., 2006). Furthermore, threats tend to hold attentional focus delaying attentional shifts (Burra et al., 2019; Fox et al., 2007; Holmes et al., 2014). Threats seem to produce these attentional biases stronger and more reliably than other emotional valences (e.g., positive or negative non-threatening) and visually salient neutral stimuli (Csathó et al., 2008; March et al., 2017; Williams et al., 2006; Zsido, Bali, et al., 2022). Attentional biases and attentional prioritisation allow our nervous system to initiate a quick and adaptive behavioural response in dangerous situations (LeDoux, 2022; Reinecke et al., 2009; Trujillo et al., 2021). However, attentional biases toward threat-related information also serve as the basis of the acquisition and maintenance of anxiety disorders, such as phobias; a bias that can be targeted in interventions to reduce fear and symptoms of anxiety (Cisler & Koster, 2010; McNally, 2018).

Yet, to date, it is still debated whether the advantage that threatening stimuli receive over neutral stimuli in visual processing is driven by visual or affective

---

[8] This chapter is based on the following article:
Pakai-Stecina, D. T.; Kiss, B. L.; Basler, J.; Zsidó, A. N. (2024). Visual features drive attentional bias for threat, *Visual Cognition, 31:8, 599-616.*
Author contribution: **DTPS**: Conceptualization, Methodology, Software, Data curation, Visualization, Formal analysis, Project administration, Funding acquisition, Writing – Original draft, Reviewing and Editing; **JB**: Data curation, Visualization, Formal analysis, Writing – Reviewing and Editing; **BK**: Data curation, Visualization, Formal analysis, Writing – Reviewing and Editing; **ANZS**: Conceptualization, Methodology, Supervision, Funding acquisition, Writing – Original draft, Reviewing and Editing.

features. According to the general feature detection theory, threatening stimuli are salient because of their specific visual features (e.g. shape, skin texture, movement) (Coelho & Purkis, 2009; Davey, 1995). Visual search studies found that curvilinear shapes (like the body of a snake) are detected faster than straight or zigzag lines (LoBue et al., 2014; Van Strien et al., 2016; Wolfe et al., 1992). An attentional advantage to downward-pointing V shape (that is geometrically similar to the head of a snake) has also been observed (Larson et al., 2007). In contrast, the fear module theory (Mineka & Öhman, 2002; Öhman & Mineka, 2001) suggests that threatening objects are salient due to their affective features (e.g., threat-relevance, valence, arousal). More specifically, according to the arousal-biased competition theory (Mather & Sutherland, 2011), emotional arousal may not only drive cognitive processes and mental representations, but it could also improve memory and modulate selective attention. Better understanding the roles of visual and affective features in the processing of threat-relevant information could have both theoretical (i.e., a unified theory) and practical (e.g., refining attention retraining methodologies) implications.

It has been suggested that task-irrelevant threatening distractors, compared to other valences and neutral distractors are more likely to capture attention and decrease performance (Burra et al., 2017, 2019; Fox et al., 2005; Mancini et al., 2020; Zsido, Bali, et al., 2022), yet prior work concerning the inhibition or suppression of threatening stimuli is still scarce. Consequently, the underlying mechanisms are still not well understood. More extensive knowledge on the matter could prove crucial because attentional inhibitory biases to threat-related information are core to the development and maintenance of anxiety and phobias (Koster, Crombez, Verschuere, & De Houwer, 2006; Koster, Crombez, Verschuere, Van Damme, et al., 2006). In contrast, for visually salient (but emotionally neutral) stimuli the signal suppression hypothesis (Sawaki & Luck, 2010a, 2011) proposes that the attentional inhibition of objects is possible. According to the hypothesis salient stimulus in the visual field creates a signal that grabs attention even though it is irrelevant to the observer's goals. This signal, however, can be actively inhibited with top-down control before attentional capture happens. This means that people are capable of attentional control through top-down, goal-directed mechanisms when they want to perform well. Inhibition also plays an important role in emotion regulation and helps us downregulate the automatic evaluation of salient objects, such as threatening stimuli (Mogg & Bradley, 2018). Studying how threatening stimuli and visually similar but neutral distractors can be effectively inhibited compared to control neutral stimuli offers an opportunity to gain deeper insights into the interplay between arousal, shape, and the advantageous role of threat in attentional processes.

Past studies suggest that the prioritisation of threats over neutral stimuli is even greater in peripheral vision (Almeida et al., 2015; Öhman et al., 2012). The brainstem-amygdala-cortex pathway (Gu et al., 2020; Liddell et al., 2005) and the dorsolateral prefrontal cortex (Cinq-Mars et al., 2022) ensures effortless evaluation and rapid orienting towards threats, both in and out of attentional focus. Stimuli that appear outside of this centre lose details, which makes it harder to identify their content. To make up for the loss of this information, spatial attention works with different eye movements to bring important objects in the environment to the centre of the visual field. However, some stimuli that are characterised by higher arousal and valence levels seem to have the ability to grab attention without corresponding eye movements (Bayle et al., 2009; Gao et al., 2017; Rigoulot et al., 2012; Zsido et al., 2019). According to a previous study (Calvo et al., 2008), the specific contents of emotional priming scenes presented in peripheral vision were not precisely processed, however, an impression was extracted that later oriented selective attention or caused false alarms for related probes in a recognition task. Consequently, presenting a threatening stimulus in the periphery should be harder to ignore than a neutral stimulus even if it has shared visual features with the threat. That is, by manipulating the eccentricity of threat-related stimuli, we may investigate the difference between the effect of visual and emotional features on visual processing.

In the present study, we aimed to test whether the visual or affective features of threat-related distractor stimuli are more important in determining attentional biases to threats. Additionally, we aimed to test whether the spatial distance (stimulus eccentricity) between the task and the distractors would have any effect on inhibition. We used a semantic vigilance task where participants had to respond to a centrally presented word and ignore task-irrelevant distractor images surrounding that word. We employed this paradigm over a more common visual search task because attention was fixated on the central task allowing for a more convenient and reliable manipulation of stimulus eccentricity. This addresses a critique of past studies (Pakai-Stecina et al., 2024). Further, using this paradigm we can extract more behavioural variables besides the usually presented accuracy and reaction time, potentially resulting in a more robust interpretation. The semantic vigilance task has been proven successful in a past attempt to demonstrate the effect of auditory negative emotions on visual attentional performance (Zsido et al., 2023).

We expected higher vigilance decrement (decline in the rate of the correct detection of signals) for threat-related (i.e., threatening and shape-matched nonthreatening) compared to (visually dissimilar) neutral stimuli. Further, we hypothesised that threatening distractors would have a more pronounced effect than nonthreatening but visually similar ones. Our second hypothesis was that the eccentricity of the distractor would have a greater effect on the performance of the threat condition compared to the shape-matched nonthreatening condition. We expected that threat distractors relative to shape-matched nonthreatening distractors, would be harder to inhibit regardless of stimulus eccentricity.

6.2 Experiment 1

We adopted a semantic vigilance task similar to previous studies (Epling et al., 2016; Zsido et al., 2023). Participants were instructed to concentrate on masked words appearing on the centre of the screen one at a time and respond to words with living meanings (e.g. dog, cat, rose) with the spacebar and ignore words with non-living meanings (e.g. rock, table, cloud). Irrelevant distractive stimuli (pictures of two living and two non-living things) also appeared on the screen at three different distances to the target word: close (visual angle of 5°), middle (30°), and far (45°). The distractor pictures were of neutral valence in general, however, there we also used two special distractors. Participants were divided into two groups, with one group (threatening distractor) seeing a threatening picture among the distractors (snake) and the other group (shape-matched distractor) seeing a neutral but shape-similar picture to the threatening one (caterpillar) among the distractors. We introduced this manipulation as a between-subject factor to avoid carry-over effects between seeing an actual threat and an object that visually resembles it. In both groups, a neutral, visually dissimilar control distractor (fish) was used alongside the threatening or the shape-matched one. Figure 6.1 shows the trial structure of the paradigm used along with sample trials from both visual feature and affective feature groups in all three distance conditions.

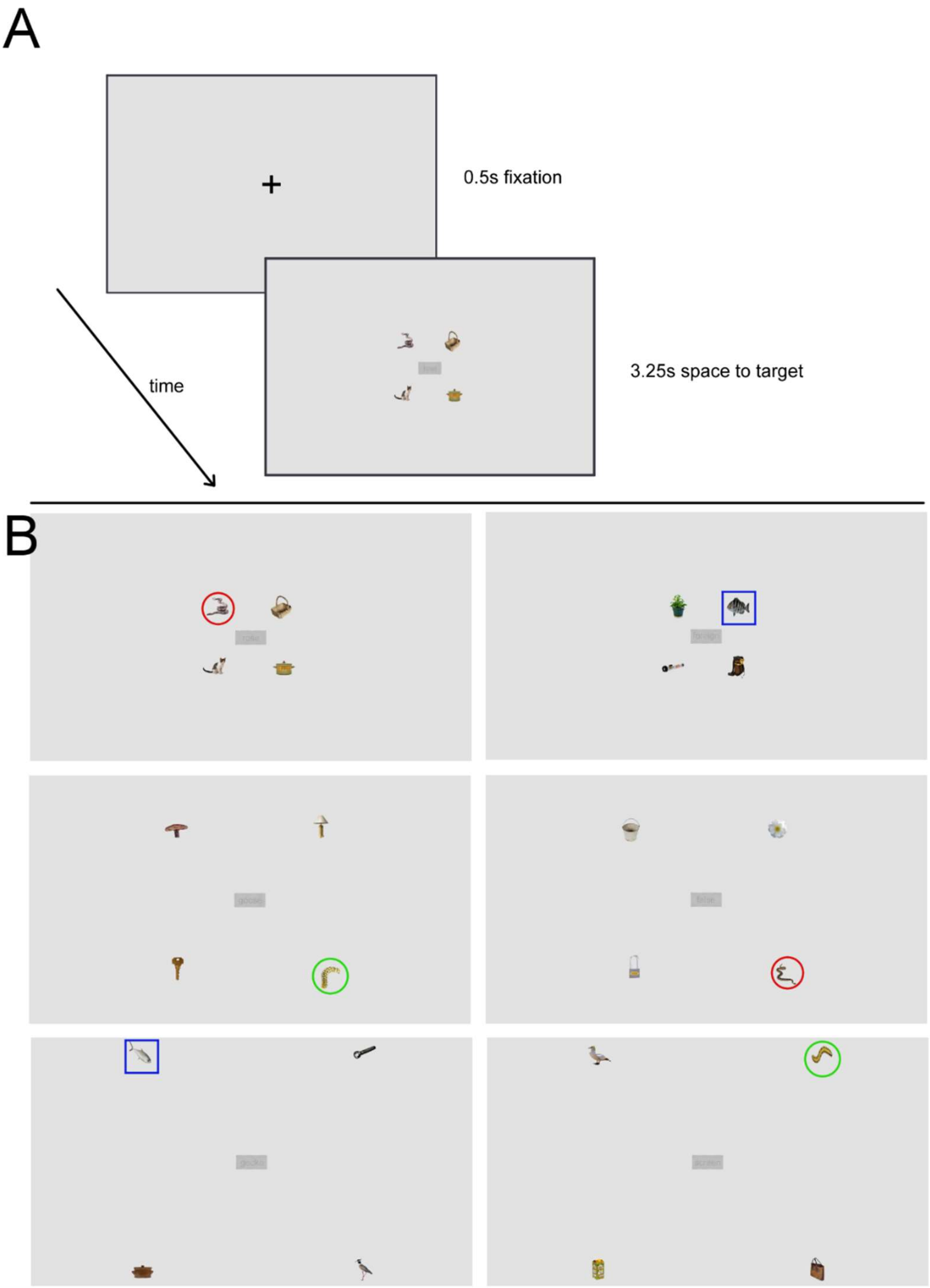

Figure 6.1 – The top panel (A) shows the trial structure of the paradigm used. First, a fixation cross of 0.5s was shown, then the semantic decision task followed. Each trial was shown for 3.25s regardless of being a target or non-target word trial and the reaction of the participants. The task was presented in three blocks (distractors in the close, middle, far positions) and the blocks were randomised. The bottom panel (B) shows sample trials from both visual feature and affective feature groups

in all three (top row: close, middle row: middle, bottom row: far) distance conditions. Affective threat-relevant distractors are marked with red circles, visual threat-relevant ones are marked with green circles and neutral control distractors are marked with blue rectangles.

6.2.1 Materials and Method

6.2.1.1 Participants

The required sample size for this experiment was determined by computing estimated statistical power based on previous studies of singletons and threat suppression (Sawaki & Luck, 2010b; Zsido et al., 2021, 2023). The analysis ($f = .40$, $1-\beta > .8$, $r = .5$) indicated that the minimum required total sample size was 12 (or 28 with a more conservative approach of $f = .25$). We recruited a total of 29 students (21 females, mean age = 22.6 SD = 3.56) who participated in exchange for course credit. The threatening distractor group comprised 16 participants (mean age = 22.1 SD = 2.45). The shape-matched distractor group comprised 13 participants (mean age = 23.2 SD = 4.63).

All participants reported normal or corrected to normal vision and normal colour vision. Two participants were excluded because they failed to follow instructions. The research was approved by the national ethics committee and was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). All participants provided written informed consent.

6.2.1.2 Stimuli

We created a semantic vigilance task based on the methodology of past studies (Epling et al., 2016). A list of words, taken from a previous study (Zsido et al., 2023), consisted of 384 nontarget (non-living) and 96 target (living) words, with a signal-to-noise ratio of 1:4 throughout the experiment (target word probability was .2 and non-target word probability was .8). At the start of the experiment, the words were sorted into six lists (counterbalanced across participants) to create a unique set of words for each condition. Table 6.1 shows the number of words and trials broken down into six conditions (2 types of distractors and 3 stimulus eccentricities). The words consisted of three to seven letters (counterbalanced across word categories and lists). The words were positioned on the centre of a 1920x1080 pixel-sized grey background with black ink colour of Arial size 9, set to a transparency level of 35% (see Figure 6.1). A mask (dark grey dots on grey background sized 135x62 pixels) was placed under the text to make it more difficult to read.

Table 6.1 – Number of words and trials broken down to six experimental blocks. Special distractors were snakes for those in the affective feature group and caterpillars for those in the visual feature group.

Condition	**Distractor type**	**Number of words**
Close condition	With special distractor (snake or caterpillar)	16 target, 64 non-target
	With neutral control distractor (fish)	16 target, 64 non-target
Middle condition	With special distractor (snake or caterpillar)	16 target, 64 non-target
	With neutral control distractor (fish)	16 target, 64 non-target
Far condition	With special distractor (snake or caterpillar)	16 target, 64 non-target
	With neutral control distractor (fish)	16 target, 64 non-target
Total		96 target, 384 non-target

The special distractor image categories (i.e., snake for the threatening and caterpillar for the shape-matched group) were determined based on the results of an online survey we conducted on an independent sample (N=77) where we asked participants to write objects that they find threatening and pair them with an object that is visually similar but is non-threatening. We used the stimuli pair that was mentioned most frequently. Our goal was to match threatening objects to ones that people find visually similar but non-threatening in line with past studies investigating similar questions (Almeida et al., 2015; LoBue, 2014; Van Strien et al., 2016; Zsido, Deak, et al., 2018; Zsido, Stecina, et al., 2022)

Distractor images were colourful photographs of real-world objects. Most of the images were collected from the Massive Memory Database (Hout et al.,

2014) and some images of the snakes, caterpillars, and fish were sourced from the Internet. None of these stimuli had a background. The images were resized to approximately the same size (i.e., no larger than 100x100 pixels) maintaining the original proportions. We used a large number of special distractors (20 exemplars per category) and other distractors (i.e., 240 categories with 15-16 exemplars per category) that were randomly sampled across trials (and participants) to ensure that distractors and targets were comparable and to reduce the possible nuisance effects of low- and mid-level visual features of the individual objects.

Distractors were placed at one of three relative distances to the four corners of the mask on every picture: visual angle of 5° (close), 30° (middle), and 45° (far). In all trials, there was either a threat-relevant special distractor (snake or caterpillar) or the neutral control distractor (fish) presented among three other random objects (e.g. butterfly, leaf, rock, clock, etc.). Special and control distractors appeared with equal probability across all word types (living and non-living), eccentricities (close, middle, and far), and experimental blocks.

6.2.1.3 Procedure

Data was collected in small groups on up to 10 computers simultaneously (with non-identical hardware and software profiles) in a computer room. Participants were seated in separate work-station booths, approximately 60 cm in front of 17-inch CRT monitors (resolution 1024x768, 4:3 aspect ratio, refresh rate of 60 Hz, colour depth of 65.536k). Stimuli were presented using the PsychoPy v3.0 software (Peirce, 2007). Data collection sessions were monitored by a research assistant. After both verbal and written instructions, participants completed a test run of 10 trials with 5 target present and 5 target-absent trials. There were no distractor pictures present during the practice trials and participants got feedback on their reactions (correct/incorrect). Practice trials were excluded from the analysis. Participants also had their chance to ask questions if they had any before starting the real experiment. Then, all participants present at the data collection site started the task at the same time, having to press the spacebar when a living word appeared on the screen. One stimulus picture was presented for 3.25 seconds preceded by a fixation cross of 0.5 seconds (see Figure 6.1). Stimuli were presented in three blocks according to the three eccentricity conditions (close, middle, far). The presentation of the blocks was randomised across participants. The task took approximately 30 minutes to complete.

6.2.1.4 Statistical Analysis

There were no outliers, defined as those more than 2 standard deviations below or above the group mean, for accuracy; while we identified and removed the outlier for reaction time (less than 3% of trials). Unlike past studies that used a visual search paradigm, we also calculated the signal detection theory metrics of d prime (d’, sensitivity) and response bias (c) in line with semantic vigilance studies (Epling et al., 2016; Zsido et al., 2023). We used the formulas d’=z(H)-z(FA) and c=-1/2*[z(H)+z(FA)] for this purpose. Here, z(H) is the z-transformed value of the proportion of corrected detection (Hits) and z(FA) is the z-transformed value of the proportion of False Alarms.

Statistical analyses were completed with the help of the JAMOVI Statistics Program v2.0 (Jamovi Project, 2022). We performed a 2x3x2 repeated measures analysis of variance (rANOVA) with Distractor Type (threat-related and control) and Distance (close, middle, far) as within-subject factors and the Groups (threatening and shape-matched distractor) as a between-subject factor to test the effect of threat and shape-matched threat-relevant but nonthreatening distractors on vigilance performance. The accuracy, d’, c, and RT values were analysed separately. Main effects and interactions are reported separately, paired with relevant follow-up analyses to further investigate the significant interactions. Effect sizes are also presented: partial eta squared (η2p) for the rANOVAs. Tukey corrections were used to account for multiple comparisons. Both the normality and homogeneity of variances assumptions for the ANOVA analysis were met. Please note that in the interest of brevity and clarity, the results of the statistical analyses are presented in tables. See Supplementary material 2 for the detailed descriptive statistics including accuracy, d’, c, and RT across all conditions.

6.2.2 Results

6.2.2.1 Accuracy

We began by examining accuracy to test our prediction that the performance of the threatening distractor group compared to the shape-matched distractor group would be worse for threat-related distractors compared to neutral distractors. Figure 6.2 presents the descriptive statistics; see Table 6.2 for significant statistical results. The interaction between the Distractor Type and Group was nonsignificant; thus, our hypothesis was not supported, and neither the effect of threatening nor that of visually similar stimuli was different when compared to neutral stimuli. We also expected that the threatening distractor group would be more affected by the distance of distractors than the shape-matched distractor group, with the distractors only interfering with the close distractor stimuli in the latter and interfering regardless of distance in the former group. Contrary to our hypothesis, we did not find a significant interaction between Distance, Distractor Type, and Group either.

The main effect of Distance and the interaction between Distance and Distractor Type was significant. Teasing apart the interaction revealed that the main effect of Distance was only significant in the neutral control condition. Participants were less accurate when the neutral target was close to the semantic task compared to when it was further away. The effect of Distance was nonsignificant in the Threat-relevant condition. All other effects were nonsignificant.

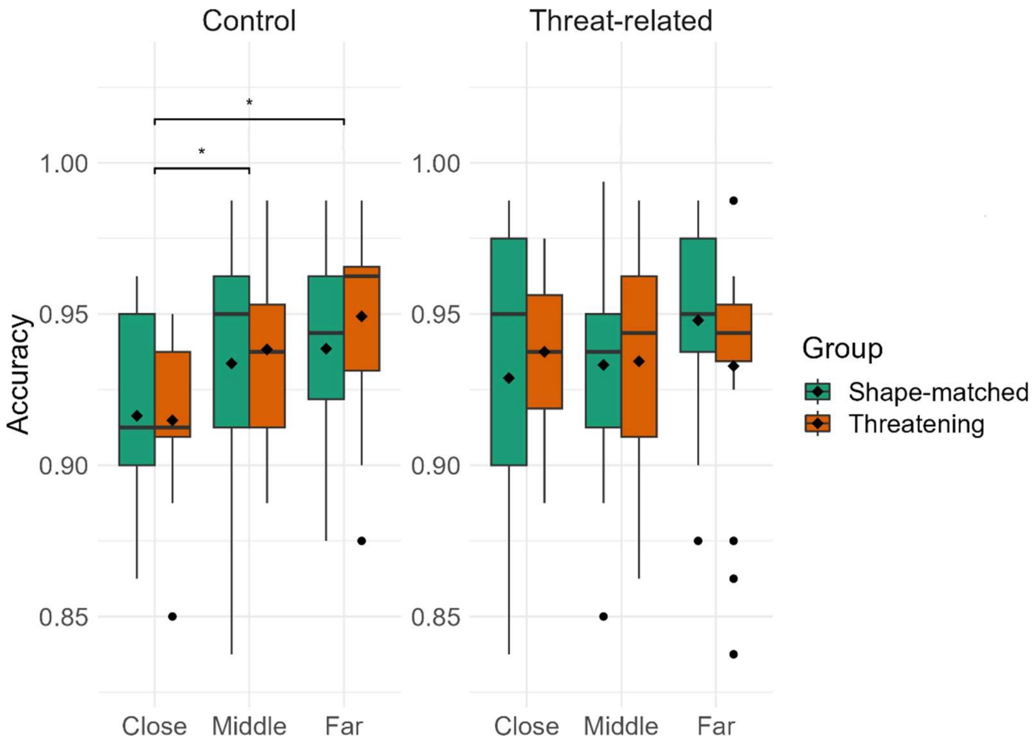

Figure 6.2 – Accuracy on the task. Results of the affective feature and visual feature groups are presented on separate panels. Findings are presented across three different distractor eccentricities and the two types of distractors. Error bars represent 95% confidence intervals.

Table 6.2 – Detailed statistical results for accuracy in Experiment 1 with main effects, interactions, follow-up ANOVAs, and pairwise comparisons.

		df	**F/t**	**p**	**η²p**
Type		1, 27	0.366	0.550	0.013
Type ✻ Groups		1, 27	1.076	0.309	0.038
Distance		**2, 54**	**8.660**	**< .001**	**0.243**
	Close – Middle	**27**	**-3.747**	**0.002**	
	Close – Far	**27**	**-3.564**	**0.004**	
	Middle – Far	27	-0.520	0.862	
Distance ✻ Groups		2, 54	0.642	0.530	0.023
Type ✻ Distance		**2, 54**	**3.970**	**0.025**	**0.128**
Threat relevant		2, 54	0.403	0.670	0.014
Non-threatening control		**2, 54**	**14.2**	**< .001**	**0.337**
	Close – Middle	**27**	**-5.012**	**< .001**	
	Close – Far	**27**	**-4.749**	**< .001**	

Measurement	Effect	df	F/t	p	η²p
	Middle – Far	27	-0.780	0.718	
Type ✻ Distance ✻ Groups		2, 54	1.580	0.215	0.055
Groups		1, 27	0.0858	0.772	0.003

Descriptive data for accuracy in Experiment 1 presented separately across the two groups and different conditions. Mean values and 95% confidence intervals are presented.

Accuracy				95% Confidence Interval	
Groups	**Type**	**Distance**	**Mean**	**Lower**	**Upper**
Visual feature	Threat-relevant	Close	0.929	0.903	0.954
		Middle	0.933	0.912	0.954
		Far	0.936	0.909	0.962
	Non-threatening control	Close	0.916	0.900	0.933
		Middle	0.934	0.913	0.954
		Far	0.930	0.908	0.951
Affective feature	Threat-relevant	Close	0.930	0.907	0.954
		Middle	0.934	0.915	0.954
		Far	0.933	0.909	0.957
	Non-threatening control	Close	0.915	0.900	0.930
		Middle	0.938	0.920	0.957
		Far	0.949	0.930	0.968

6.2.2.2 d' Scores

We then examined d’ scores to check for our predictions. Figure 6.3 presents the descriptive statistics; see Table 6.3 for the statistical results. Contrary to our expectations both the Distractor Type x Group and the Distance x Distractor Type x Group interactions were nonsignificant, meaning that neither the effect of threatening nor that of visually similar stimuli was different when compared to neutral stimuli.

Again, both the Distance main effect and Distance x Distractor Type interaction were significant. The Distance effect was only significant for the control but not the threat-relevant conditions. That is, participants’ performance was worse in the neutral control condition when distractors were presented close to the target word than when they were presented in middle and far eccentricities. All other effects were nonsignificant.

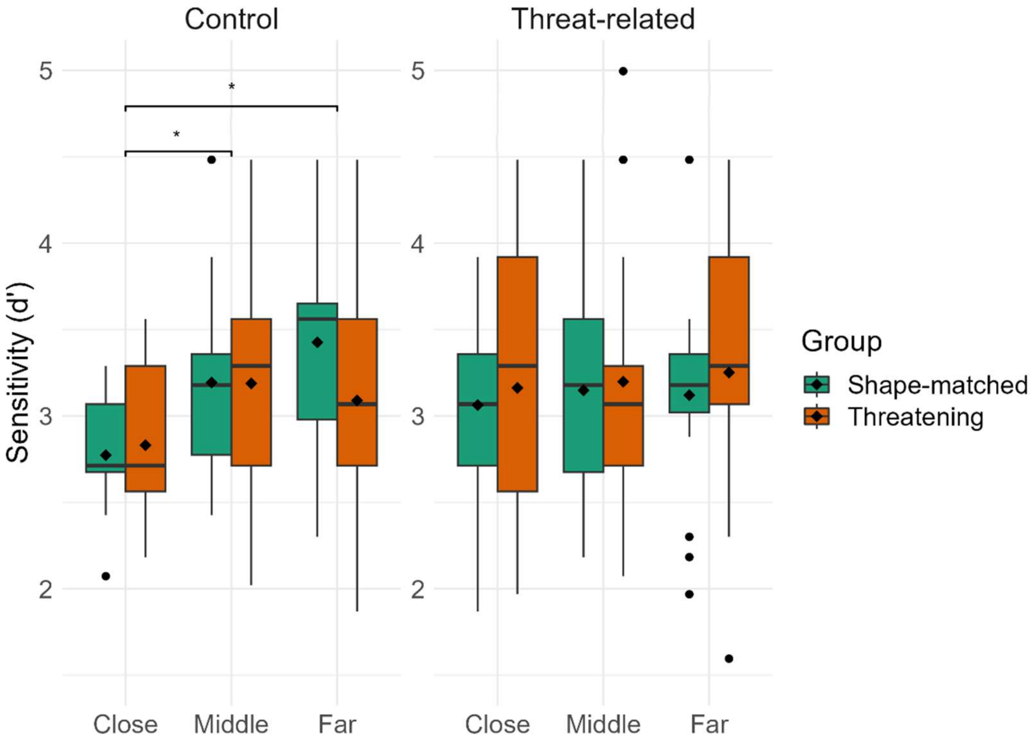

Figure 6.3 – Sensitivity (d’) scores on the task. Results of the affective feature and visual feature groups are presented on separate panels. Findings are presented across three different distractor eccentricities and the two types of distractors. Error bars represent 95% confidence intervals.

Table 6.3 – Detailed statistical results for sensitivity (d’) in Experiment 1 with main effects, interactions, follow-up ANOVAs, and pairwise comparisons.

		df	F/t	p	η²p
Type		1, 27	1.290	0.266	0.046
Type ✻ Groups		1, 27	2.100	0.159	0.072
Distance		**2, 54**	**8.496**	**< .001**	**0.239**
	Close – Middle	**27**	**-3.379**	**0.006**	
	Close – Far	**27**	**-3.844**	**0.002**	
	Middle – Far	27	-0.551	0.847	
Distance ✻ Groups		2, 54	0.899	0.413	0.032
Type ✻ Distance		**2, 54**	**4.684**	**0.013**	**0.148**
	Threat relevant	2, 54	0.309	0.735	0.011

		df	F/t	p	η^2p
Non-threatening control		**2, 54**	**14.7**	**< .001**	**0.345**
	Close – Middle	**27**	**-4.651**	**< .001**	
	Close – Far	**27**	**-4.819**	**< .001**	
	Middle – Far	27	-0.864	0.667	
Type ✻ Distance ✻ Groups		2, 54	1.602	0.211	0.056
Groups		1, 27	<.001	0.997	0.000

Descriptive data for sensitivity (d’) in Experiment 1 presented separately across the two groups and different conditions. Mean values and 95% confidence intervals are presented.

		Sensitivity (d')		95% Confidence Interval	
Groups	**Type**	**Distance**	**Mean**	**Lower**	**Upper**
Visual feature	Threat-relevant	Close	3.06	2.71	3.42
		Middle	3.15	2.79	3.51
		Far	3.12	2.77	3.47
	Non-threatening control	Close	2.77	2.57	2.97
		Middle	3.19	2.88	3.51
		Far	3.43	3.10	3.76
Affective feature	Threat-relevant	Close	3.16	2.77	3.55
		Middle	3.20	2.80	3.60
		Far	3.25	2.86	3.64
	Non-threatening control	Close	2.83	2.61	3.05
		Middle	3.19	2.84	3.54
		Far	3.09	2.72	3.46

6.2.2.3 c Scores

We next examined the c scores, again to check for our predictions regarding the threat-relevant distractors. Figure 6.4 presents the descriptive statistics; see Table 6.4 for the statistical results. Contrary to our expectations, again, both the Distractor Type x Group and the Distance x Distractor Type x Group interactions were nonsignificant, meaning that neither the effect of threatening nor that of visually similar stimuli was different when compared to neutral stimuli.

The main effect of Distance and the interaction between Distance and Distractor Type were significant. The Distance effect was only significant for the control, not for the threat-relevant conditions. That is, participants' performance was worse in the control condition when distractors were presented close to the target word than when they were presented in middle and far eccentricities. All other effects were nonsignificant.

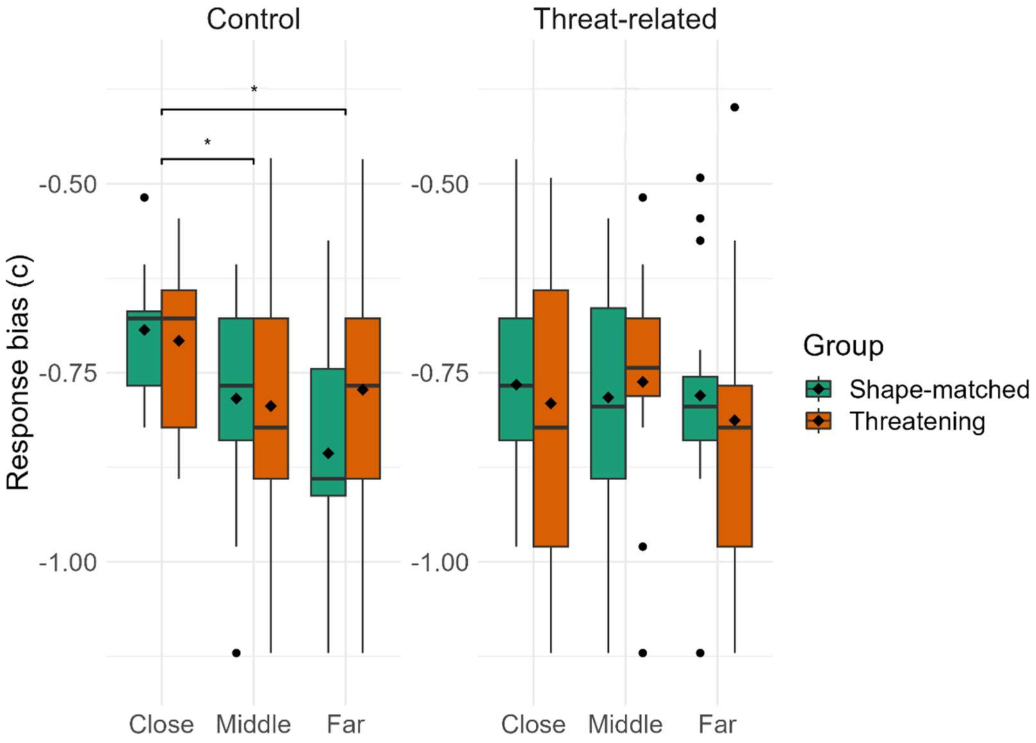

Figure 6.4 – Response bias (c) scores on the task. Results of the affective feature (right) and visual feature (left) groups are presented on separate panels. Findings are presented across three different distractor eccentricities and the two types of distractors. Error bars represent 95% confidence intervals.

Table 6.4 – Detailed statistical results for response bias (c) in Experiment 1 with main effects, interactions, follow-up ANOVAs, and pairwise comparisons.

		df	F/t	p	η^2p
Type		1, 27	1.654	0.209	0.058
Type ✻ Groups		1, 27	1.955	0.173	0.068
Distance		**2, 54**	**7.437**	**0.001**	**0.216**
	Close – Middle	**27**	**2.859**	**0.021**	
	Close – Far	**27**	**3.844**	**0.002**	
	Middle – Far	27	0.816	0.697	
Distance ✻ Groups		2, 54	0.937	0.398	0.034
Type ✻ Distance		**2, 54**	**4.424**	**0.017**	**0.141**
Threat relevant		2, 54	0.278	0.758	0.010
Non-threatening control		**2, 54**	**12.8**	**< .001**	**0.314**
	Close – Middle	**27**	**4.01**	**0.001**	
	Close – Far	**27**	**4.82**	**< .001**	
	Middle – Far	27	1.15	0.492	
Type ✻ Distance ✻ Groups		2, 54	1.698	0.193	0.059
Groups		1, 27	0.002	0.961	0.000

Descriptive data for response bias (c) in Experiment 1 presented separately across the two groups and different conditions. Mean values and 95% confidence intervals are presented.

			Bias (c)		
				95% Confidence Interval	
Groups	**Type**	**Distance**	**Mean**	**Lower**	**Upper**
Visual feature	Threat-relevant	Close	-0.766	-0.854	-0.678
		Middle	-0.783	-0.874	-0.691
		Far	-0.780	-0.868	-0.692
	Non-threatening control	Close	-0.693	-0.743	-0.643
		Middle	-0.784	-0.866	-0.702
		Far	-0.857	-0.939	-0.774
Affective feature	Threat-relevant	Close	-0.791	-0.888	-0.693
		Middle	-0.800	-0.901	-0.698
		Far	-0.813	-0.910	-0.716
	Non-threatening control	Close	-0.708	-0.763	-0.652
		Middle	-0.794	-0.885	-0.703
		Far	-0.772	-0.864	-0.681

6.2.2.4 Reaction Time

We next examined the RTs to check for our predictions regarding the threat-relevant distractors. Figure 6.5 presents the descriptive statistics; see Table 6.5 for the statistical results. Contrary to our expectations, again, both the Distractor Type x Group and the Distance x Distractor Type x Group interactions were nonsignificant meaning that neither the effect of threatening nor that of visually similar stimuli was different when compared to neutral stimuli.

While the interaction between Distance and Distractor Type was significant, the follow-up analyses revealed nonsignificant main effects of Distance in both the control (p=.548) and the threat-relevant conditions (p=.069). All other effects were nonsignificant.

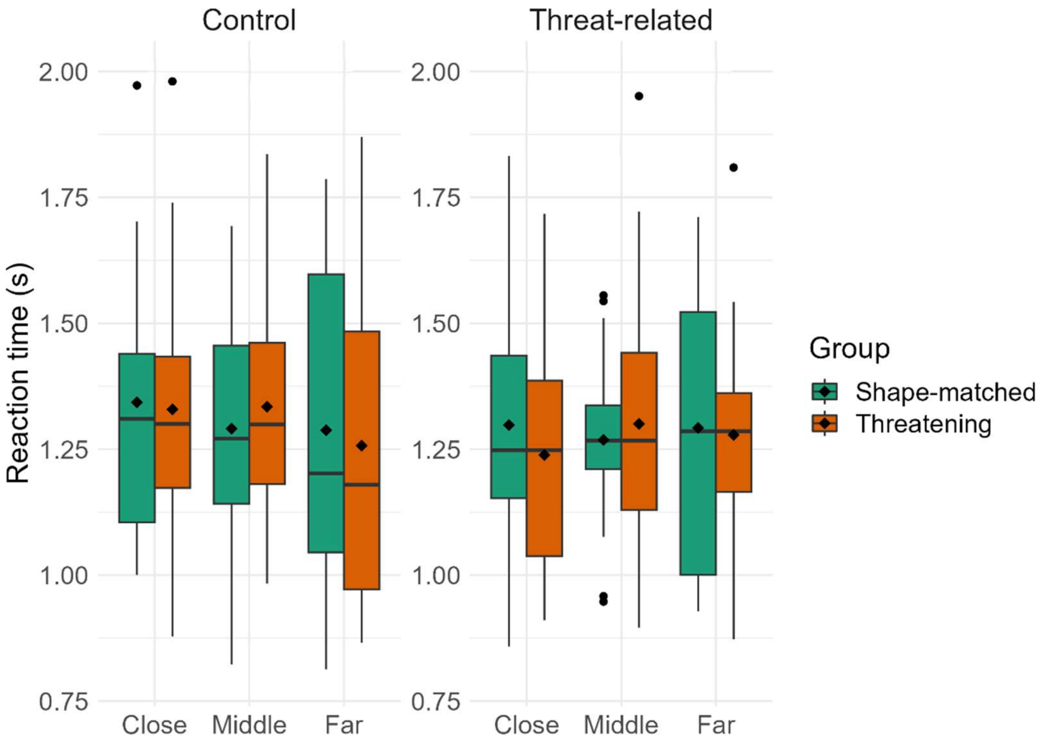

Figure 6.5 – RT scores on the task. Results of the affective feature (right) and visual feature (left) groups are presented on separate panels. Findings are presented across three different distractor eccentricities and the two types of distractors. Error bars represent 95% confidence intervals.

Table 6.5 – Detailed statistical results for reaction time in Experiment 1 with main effects, interactions, follow-up ANOVAs, and pairwise comparisons.

		df	F/t	p	η^2p
Type		1, 27	0.9200	0.346	0.033
Type ✻ Groups		1, 27	0.5236	0.476	0.019
Distance		2, 54	0.5606	0.574	0.020
Distance ✻ Groups		2, 54	0.4763	0.624	0.017
Type ✻ Distance		**2, 54**	**3.3520**	**0.042**	**0.110**
Threat relevant		2, 54	0.608	0.548	0.021
Non-threatening control		2, 54	2.81	0.069	0.091
	Close – Middle	27	1.26	0.428	
	Close – Far	27	1.95	0.144	
	Middle – Far	27	1.57	0.275	
Type ✻ Distance ✻ Groups		2, 54	0.0348	0.966	0.001
Groups		1, 27	0.0338	0.856	0.001

Descriptive data for reaction time in Experiment 1 presented separately across the two groups and different conditions. Mean values and 95% confidence intervals are presented.

		Reaction time			
				95% Confidence Interval	
Groups	Type	Distance	Mean	Lower	Upper
Visual feature	Threat-relevant	Close	1.26	1.10	1.42
		Middle	1.27	1.11	1.43
		Far	1.29	1.14	1.44
	Non-threatening control	Close	1.34	1.18	1.51
		Middle	1.25	1.09	1.41
		Far	1.24	1.05	1.44
Affective feature	Threat-relevant	Close	1.20	1.06	1.35
		Middle	1.26	1.12	1.40
		Far	1.24	1.11	1.38
	Non-threatening control	Close	1.33	1.18	1.48
		Middle	1.30	1.16	1.44
		Far	1.22	1.04	1.40

6.2.3 Discussion

The main goal of Experiment 1 was to determine whether visual or affective features of a threat-relevant distractor stimulus are more defining in attentional capture and how the effect changes with the spatial distance between the task and the distractors. Overall, we found evidence of a distance effect; that is, the performance of participants was lower when a distractor appeared close to the task compared to when it appeared in the periphery. Surprisingly, however, we found no evidence of differences in performance for threatening (snake) versus shape-matched (caterpillar) distractors. In addition to this, the distance effect was only observable for the neutral control distractor (fish) but not for the threat-relevant distractors. The results may provide evidence for an attentional prioritisation of threat-related information based on visual features.

Before we can dive into the discussion of the possible theoretical explanations behind these results, we need to check whether the results from a unique class of images (i.e., snakes and caterpillars) can be generalised to other types of threatening information. Further, the lack of significant results for the threat-related distractors might mean that the threat manipulation failed. Consequently, we next sought to rule out stimulus idiosyncrasies or flukish results as an explanation for what we observed. For the dual purposes of replication and to rule out stimulus idiosyncrasies (and to test whether the visual or affective features of the threat caused this pattern of results), we conducted a second experiment.

6.3 Experiment 2

In Experiment 2, participants performed the same semantic vigilance task as in Experiment 1. Here, in addition to the snake, the threatening special distractor category also included spiders, syringes, and guns; consequently, in addition to caterpillars, the shape-matched special distractor category also included stinkbugs, knitting-pins, and hairdryers; finally, in addition to fish, the neutral control distractor category included cats, kitchen utensils, and perfume bottles. This was necessary to address the concern left by Experiment 1 that our results were not generalizable to threats. Further, the sample size in Experiment 1 was rather low (although the minimum sample size requirement was met), which also precluded making generalised claims about the results. Therefore, we aimed to collect a significantly larger number of responses in Experiment 2. Our modified design thus allowed us to explore the effects of affective and visual features of a threat-related stimulus more broadly.

6.3.1 Materials and Method

6.3.1.1 Participants

We sought to double the sample size of Experiment 1. We collected data from 58 students (mean age = 20.7, SD = 1.63) for partial course credit. Five participants were identified as outliers (defined as those more than 2 standard deviations below or above the group mean) and removed, resulting in a total sample size of 53 participants. The threatening distractor group comprised 26. The shape-matched distractor group comprised 27 participants.

All participants reported normal or corrected to normal vision and normal colour vision. The research was approved by the national ethics committee and was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). All participants provided written informed consent.

6.3.1.2 Stimuli and Procedure

The semantic vigilance task and the distractor images were identical to Experiment 1. In all trials, there was either a special distractor (threatening: snake, spider, syringe, gun or shape-matched nonthreatening: caterpillar, stinkbug, knitting-pin, hairdryer) or a neutral control distractor (fish, cat, kitchen utensil, perfume bottle) presented among three other random objects.

Data was collected in small groups on up to 10 computers simultaneously (with non-identical hardware and software profiles) in a computer room. Participants were seated in separate work-station booths, approximately 60 cm in front of the computer screens. In contrast to Experiment 1, stimuli were presented on 21.5-inch LCD screens (resolution 1920x1080, 16:9 aspect ratio, refresh rate of

60 Hz, colour depth of 16.7M) because we did not have access to a computer room with CRT monitors.

6.3.1.3 Statistical Analysis

We removed participants with outlier values, defined as those more than 2 standard deviations below or above the group mean (less than 5% of trials). We calculated the signal detection theory metrics of d’ and c.

Statistical analyses were completed with the help of the JAMOVI Statistics Program v2.0 (Jamovi Project, 2022). We performed a 2x3x2 repeated measures analysis of variance (rANOVA) to test the effect of Distractor Type (threat-related and control) and Distance (close, middle, far) as within-subject factors and the Groups (threatening and shape-matched) as a between-subject factor on performance (indicated by accuracy, d’, c, and RT). Only correct trial RTs were analysed. Both the normality and homogeneity of variances assumptions for the ANOVA analysis were met. Statistical results are presented in tables instead of in text to make the description of the results easier to follow. See Supplementary material 2 for the detailed descriptive statistics including accuracy, d, c, and RT across all conditions.

6.3.2 Results

6.3.2.1 Accuracy

We began by examining accuracy to test our prediction that the performance of the threatening distractor group compared to the shape-matched distractor group would be worse for threat-related distractors compared to neutral control distractors. Figure 6.6 presents the descriptive statistics; see Table 6.6 for the statistical results. Replicating the results of Experiment 1, the interaction between Distractor Type and Group was nonsignificant; thus, our hypothesis was not supported, and neither the effect of threatening nor that of visually similar stimuli was different when compared to neutral stimuli. We also expected that the threatening distractor group would be more affected by the distance of distractors than the shape-matched distractor group, with the distractors only interfering with the close distractor stimuli in the latter and interfering regardless of distance in the former group. Again, in line with the results of Experiment 1 but contrary to our hypothesis, we did not find a significant interaction between Distance, Distractor Type, and Group either.

Similarly, to Experiment 1, the main effect of Distance and the interaction between Distance and Distractor Type was significant. Teasing apart the interaction revealed that the main effect of Distance was only significant in the neutral control condition. Participants were less accurate when the neutral target was close to the semantic task compared to when it was further away. The effect of Distance was nonsignificant in the Threat-relevant condition. All other effects were nonsignificant.

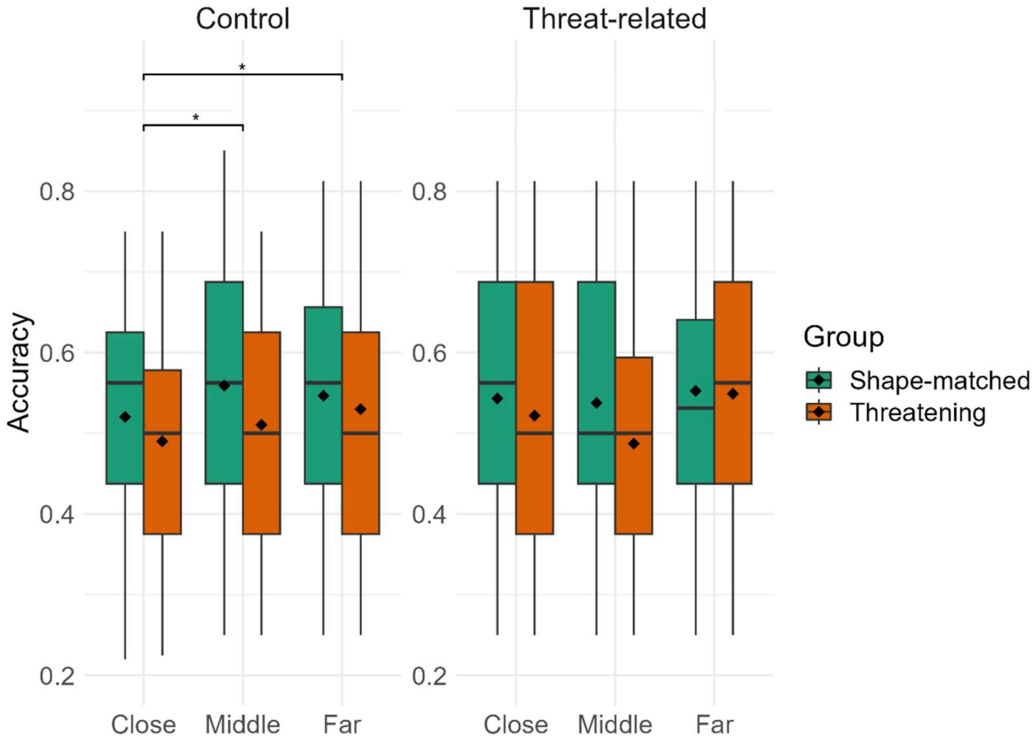

Figure 6.6 – Accuracy on the task. Results of the affective feature and visual feature groups are presented on separate panels. Findings are presented across three different distractor eccentricities and the two types of distractors. Error bars represent 95% confidence intervals.

Table 6.6 – Detailed statistical results for accuracy in Experiment 2 with main effects, interactions, follow-up ANOVAs, and pairwise comparisons.

		df	F/t	p	η^2p
Type		1, 51	0.981	0.327	0.019
Type ✻ Groups		1, 51	0.335	0.566	0.007
Distance		**2, 102**	**3.165**	**0.046**	**0.058**
	Close – Middle	51.0	1.524	0.288	
	Close – Far	**51.0**	**-2.430**	**0.048**	
	Middle – Far	51.0	-1.000	0.580	
Distance ✻ Groups		2, 102	0.367	0.694	0.007
Type ✻ Distance		**2, 102**	**4.454**	**0.014**	**0.080**
Threat relevant		2, 102	2.040	0.134	0.030
Non-threatening control		**2, 102**	**3.35**	**0.038**	**0.048**
	Close – Middle	**51.0**	**-2.0198**	**0.042**	
	Close – Far	**51.0**	**-2.3464**	**0.022**	
	Middle – Far	51.0	-0.0449	0.964	
Type ✻ Distance ✻ Groups		2, 102	0.488	0.615	0.009
Groups		1, 51	0.00949	0.923	0.000

Descriptive data for accuracy in Experiment 2 presented separately across the two groups and different conditions. Mean values and 95% confidence intervals are presented.

		Accuracy			
				95% Confidence Interval	
Groups	**Type**	**Distance**	**Mean**	**Lower**	**Upper**
Visual feature	Threat-relevant	Close	0.523	0.449	0.577
		Middle	0.513	0.466	0.581
		Far	0.569	0.510	0.629
	Non-threatening control	Close	0.466	0.498	0.616
		Middle	0.557	0.411	0.521
		Far	0.512	0.457	0.567
Affective feature	Threat-relevant	Close	0.538	0.425	0.556
		Middle	0.490	0.480	0.597
		Far	0.543	0.482	0.604
	Non-threatening control	Close	0.468	0.481	0.601
		Middle	0.541	0.411	0.524
		Far	0.545	0.489	0.601

6.3.2.2 d' Scores

We then examined d' scores to check for our predictions. Figure 6.7 presents the descriptive statistics; see Table 6.7 for statistical results. Replicating the results of Experiment 1, both the Distractor Type x Group and the Distance x Distractor Type x Group interactions were nonsignificant. Neither the effect of threatening nor that of visually similar stimuli was different when compared to neutral stimuli.

Similarly, to Experiment 1, the Distance x Distractor Type interaction was significant with the Distance effect only being significant for the neutral control but not the threat-relevant conditions. That is, participants' performance was worse in the neutral control condition when distractors were presented close to the target word than when they were presented in middle and far eccentricities. All other effects were nonsignificant.

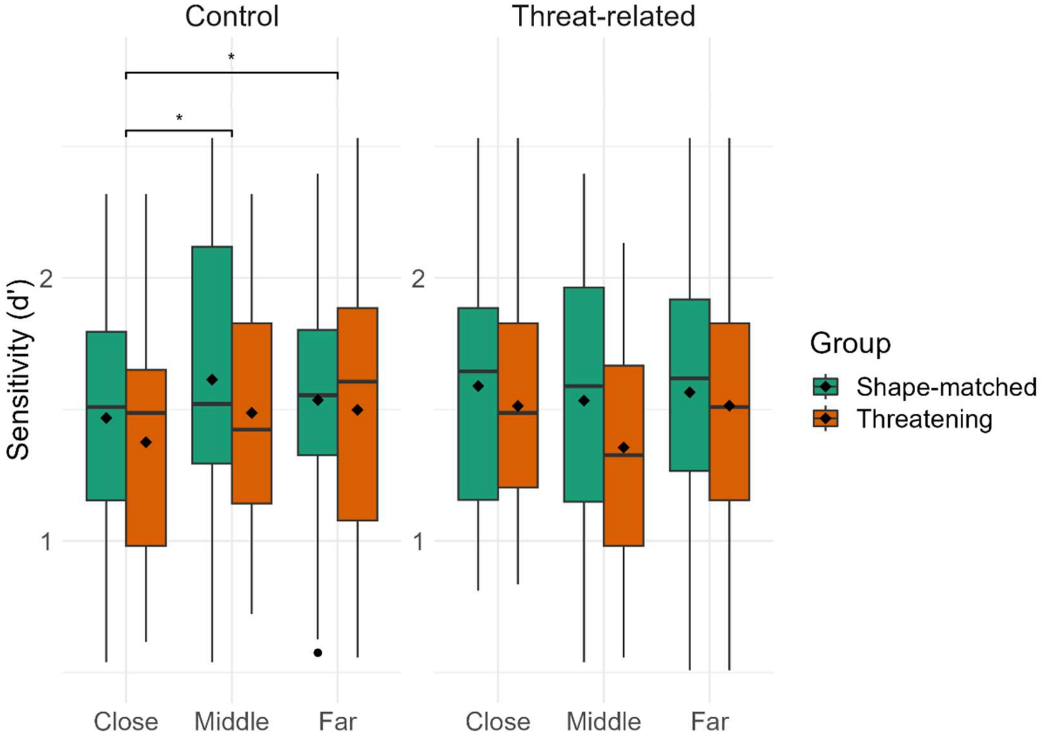

Figure 6.7 – Sensitivity (d') scores on the task. Results of the affective feature and visual feature groups are presented on separate panels. Findings are presented across three different distractor eccentricities and the two types of distractors. Error bars represent 95% confidence intervals.

Table 6.7 – Detailed statistical results for sensitivity (d’) in Experiment 2 with main effects, interactions, follow-up ANOVAs, and pairwise comparisons.

	df	F/t	p	η^2p
Type	1, 51	0.765	0.386	0.015
Type ✻ Groups	1, 51	1.614	0.210	0.031
Distance	2, 102	2.271	0.108	0.043
Distance ✻ Groups	2, 102	0.141	0.869	0.003
Type ✻ Distance	**2, 102**	**4.191**	**0.018**	**0.076**
Threat relevant	2, 102	0.859	0.426	0.013
Non-threatening control	**2, 102**	**3.67**	**0.028**	**0.052**
Close – Middle	**51.0**	**-2.238**	**0.029**	
Close – Far	**51.0**	**-2.383**	**0.020**	
Middle – Far	51.0	0.122	0.903	
Type ✻ Distance ✻ Groups	2, 102	0.899	0.410	0.017
Groups	1, 51	0.270	0.606	0.005

Descriptive data for sensitivity (d’) in Experiment 2 presented separately across the two groups and different conditions. Mean values and 95% confidence intervals are presented.

		Sensitivity (d')		95% Confidence Interval	
Groups	**Type**	**Distance**	**Mean**	**Lower**	**Upper**
Visual feature	Threat-relevant	Close	1.51	1.35	1.68
		Middle	1.49	1.28	1.69
		Far	1.59	1.38	1.80
	Non-threatening control	Close	1.28	1.11	1.45
		Middle	1.56	1.37	1.75
		Far	1.45	1.29	1.60
Affective feature	Threat-relevant	Close	1.50	1.33	1.67
		Middle	1.39	1.17	1.60
		Far	1.40	1.19	1.62
	Non-threatening control	Close	1.27	1.10	1.44
		Middle	1.51	1.32	1.71
		Far	1.56	1.40	1.72

6.3.2.3 c Scores

We next examined the c scores, again to check our predictions regarding the threat-relevant distractors. Figure 6.8 presents the descriptive statistics; see Table 6.8 for the statistical results. Contrary to our expectations, but in line with Experiment 1, both the Distractor Type x Group and the Distance x Distractor Type x Group interactions were nonsignificant meaning that neither the effect of threatening nor that of visually similar stimuli was different when compared to neutral stimuli.

Again, similarly, to Experiment 1, the main effect of Distance and the interaction between Distance and Distractor Type were significant. The Distance effect was only significant for the neutral control but not the threat-relevant conditions. That is, participants' performance was worse in the control condition when distractors were presented close to the target word than when they were presented in middle and far eccentricities. All other effects were nonsignificant.

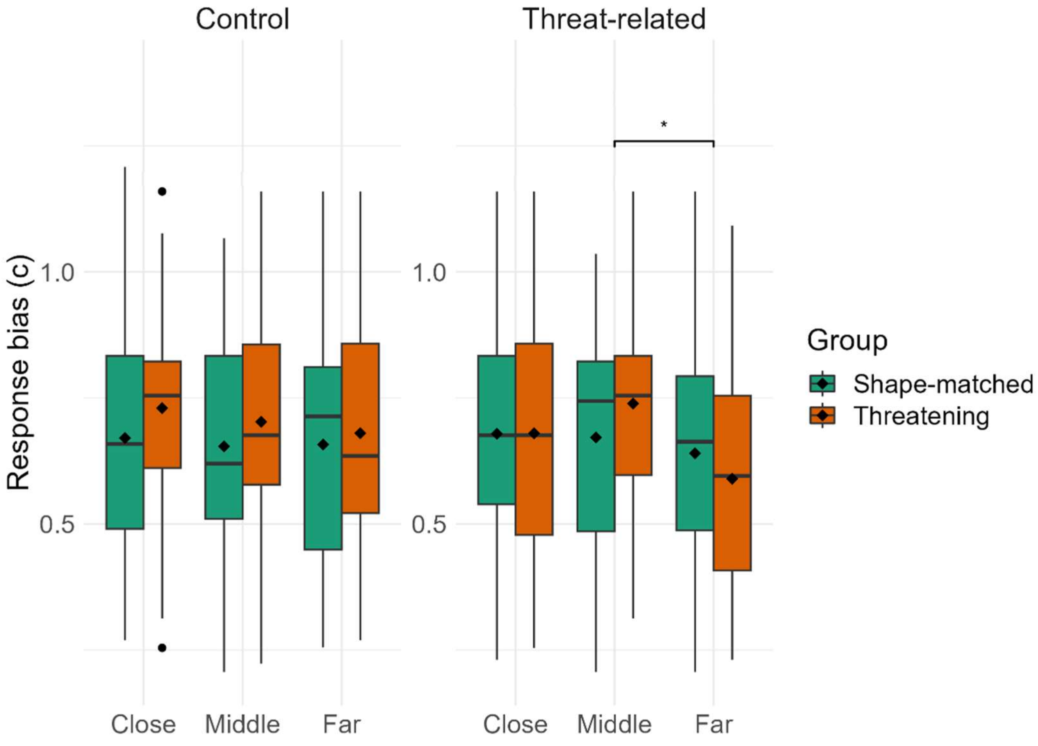

Figure 6.8 – Response bias (c) scores on the task. Results of the affective feature (right) and visual feature (left) groups are presented on separate panels. Findings

are presented across three different distractor eccentricities and the two types of distractors. Error bars represent 95% confidence intervals.

Table 6.8 – Detailed statistical results for response bias (c) in Experiment 2 with main effects, interactions, follow-up ANOVAs, and pairwise comparisons.

		df	**F/t**	**p**	**η^2p**
Type		1, 51	1.1137	0.296	0.021
Type ✻ Groups		1, 51	0.1330	0.717	0.003
Distance		**2, 102**	**3.2757**	**0.042**	**0.060**
	Close – Middle	51.0	-1.01	0.576	
	Close – Far	**51.0**	**1.57**	**0.035**	
	Middle – Far	51.0	2.56	0.269	
Distance ✻ Groups		2, 102	0.7006	0.499	0.014
Type ✻ Distance		**2, 102**	**4.4317**	**0.014**	**0.080**
Threat relevant		**2, 102**	**3.73**	**0.027**	**0.054**
	Close – Middle	51.0	-1.13	0.263	
	Close – Far	51.0	1.48	0.142	
	Middle – Far	**51.0**	**2.99**	**0.004**	
Non-threatening control		2, 102	1.85	0.161	0.027
Type ✻ Distance ✻ Groups		2, 102	0.0688	0.934	0.001
Groups		1, 51	0.118	0.733	0.002

Descriptive data for response bias (c) in Experiment 2 presented separately across the two groups and different conditions. Mean values and 95% confidence intervals are presented.

			Bias (c)		
				95% Confidence Interval	
Groups	**Type**	**Distance**	**Mean**	**Lower**	**Upper**
Visual feature	Threat-relevant	Close	0.698	0.611	0.785
		Middle	0.701	0.615	0.788
		Far	0.607	0.514	0.699
	Non-threatening control	Close	0.736	0.644	0.827
		Middle	0.624	0.538	0.709
		Far	0.691	0.608	0.773
Affective feature	Threat-relevant	Close	0.645	0.556	0.734
		Middle	0.717	0.628	0.805
		Far	0.581	0.487	0.675

				95% Confidence Interval	
Groups	**Type**	**Distance**	**Mean**	**Lower**	**Upper**
	Non-threatening control	Close	0.720	0.627	0.814
		Middle	0.650	0.563	0.737
		Far	0.662	0.578	0.746

6.3.2.4 Reaction Time

We next examined the RTs to check our predictions regarding the threat-relevant distractors. Figure 6.9 presents the descriptive statistics; see Table 6.9 for the statistical results. Contrary to our expectations, replicating the results of Experiment 1, the Distractor Type x Group and the Distance x Distractor Type x Group interactions were nonsignificant meaning that neither the effect of threatening nor that of visually similar stimuli was different when compared to neutral stimuli.

In contrast to previous results, the interaction between Distance and Group was significant; however, the follow-up analyses revealed that the main effect of Distance was only significant in the neutral control but not in the threat-relevant group. In the control group, participants were faster to respond when the distractors were presented far from the target word than when they were presented in close and middle eccentricities. All other effects were nonsignificant.

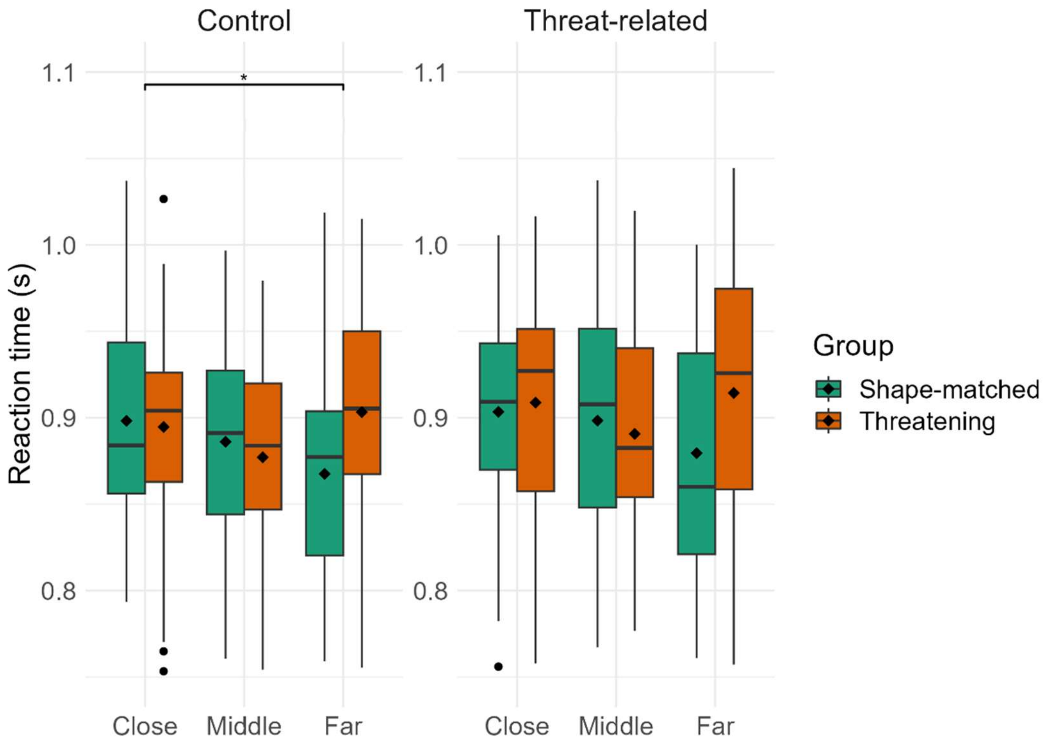

Figure 6.9 – RT scores on the task. Results of the affective feature (right) and visual feature (left) groups are presented on separate panels. Findings are presented across three different distractor eccentricities and the two types of distractors. Error bars represent 95% confidence intervals.

Table 6.9 – Detailed statistical results for reaction time in Experiment 2 with main effects, interactions, follow-up ANOVAs, and pairwise comparisons.

			df	F/t	p	η^2p
Type			**1, 51**	**4.296**	**0.043**	**0.072**
Type ✻ Groups			1, 51	0.307	0.582	0.006
Distance			2, 102	0.940	0.394	0.017
Distance ✻ Groups			**2, 102**	**4.313**	**0.016**	**0.073**
	Threat relevant		2, 102	2.267	0.114	0.080
	Non-threatening control		2, 102	3.06	0.054	0.096
		Close – Middle	51.0	0.664	0.512	
		Close – Far	**51.0**	**2.290**	**0.029**	
		Middle – Far	51.0	1.671	0.105	
Type ✻ Distance			2, 102	1.006	0.369	0.018
Type ✻ Distance ✻ Groups			2, 102	0.176	0.839	0.003

	df	F/t	p	η²p
Groups	1, 51	2.21	0.143	0.039

Descriptive data for reaction time in Experiment 2 presented separately across the two groups and different conditions. Mean values and 95% confidence intervals are presented.

			Reaction time	95% Confidence Interval	
Groups	**Type**	**Distance**	**Mean**	**Lower**	**Upper**
Visual feature	Threat-relevant	Close	0.896	0.874	0.918
		Middle	0.878	0.856	0.900
		Far	0.871	0.846	0.896
	Non-threatening control	Close	0.877	0.852	0.903
		Middle	0.884	0.862	0.905
		Far	0.855	0.830	0.880
Affective feature	Threat-relevant	Close	0.905	0.882	0.929
		Middle	0.884	0.861	0.907
		Far	0.913	0.886	0.939
	Non-threatening control	Close	0.882	0.855	0.909
		Middle	0.873	0.851	0.896
		Far	0.896	0.870	0.922

6.3.3 Discussion

In Experiment 2, we replicated the results of Experiment 1; that is, performance was lower when a neutral distractor appeared close to the task compared to when it was on the periphery. We found no such effect for threat-relevant distractors; further, we did not find any differences between the threatening distractor and shape-matched distractor groups. This was true even though, compared to Experiment 1, we used other types of threatening stimuli in addition to snakes and caterpillars. Thus, the effects we found in Experiment 1 are likely not due to the specific shape or a possible difference in the visibility of the targets but rather may be generalised to a wider range of threat-relevant information. Similarly, it seems unlikely that the results are due to a failed threat manipulation because the effect of threat-related distractors was different compared to the baseline effect seen for the neutral control distractors in both the threatening distractor and the shape-matched distractor groups. In contrast to Experiment 1, here we also found a distance effect for threat-relevant targets for response bias; that is, the conservative response bias was lower when the distractor was presented farther from the task compared to when it appeared closer. In sum, again, the results of Experiment 2 suggest an attentional prioritisation of threat-related information based on visual features.

6.4 General Discussion

The goal of our two experiments was to test if salient but task-irrelevant stimuli, i.e. threat-related distractors, capture attention during a semantic vigilance task at different stimulus eccentricities. Further, we sought to investigate whether the attentional capture is driven by the affective (threat value) or visual (shape) features of a threatening stimulus. We did find an effect of stimulus eccentricity for neutral control distractors – performance was lower when they were presented closer (compared to farther away) to the task. Contrary to our expectations, we did not find such an effect for threat-related distractors. Also contradicting our hypothesis, we did not find a difference in task performance between the threatening and shape-matched distractor groups.

Our results suggest that shape information alone, if threat-related, can affect task performance similarly to actual threats. This can be seen as further proof of the general feature detection theory (Coelho & Purkis, 2009; Davey, 1995) and the smoke detector principle – i.e., better to err on the side of caution (Nesse, 2006). Further, this result is in line with previous experimental results indicating that shapes that are strongly associated with threats (e.g., curvy shapes – snakes, downward pointing V shapes – snakes' heads) can elicit the same responses as threatening images (of real snakes) (Larson et al., 2007; LoBue, 2014; Van Strien et al., 2016; Wolfe et al., 1992). From an evolutionary perspective, it may be simpler to encode a visual cue than an emotion. Emotion could be considered secondary in this context, activated by the processing of the visual cue via the low road (LeDoux, 2000/b; Lowe, Humphries & Ziemke, 2009). Additionally, it's noteworthy that the amygdala functions as a saliency detector, encompassing visual salience alongside emotion (Mogg & Bradley, 2018; Yin et al., 2018). Hence, even the processing of partial information through the magnocellular pathway can activate the brainstem-amygdala-cortex alarm system (Csathó et al., 2008). This implies that the participant might recognise the presence of a threatening object without discerning its specific identity. These findings suggest that the fear module theory (Öhman & Mineka, 2001) does not have any added value to the explanation of the distinguished neural and behavioural responses evoked by threatening stimuli.

Our previous study (Zsido, Stecina, et al., 2022) using the Rapid Serial Visual Presentation paradigm with task-relevant threat-related objects showed that when visual features are sufficient to discriminate the target from the other items in the stream, there was no effect of affective feature (i.e., threat level) on reaction time or accuracy. While that study was more focused on working memory resources and used task-relevant objects, our findings here are similar insofar as the visual feature alone was sufficient to elicit the same response as the affective feature of a threat. Somewhat contrary to these findings, our recent study (Pakai-Stecina et al., 2024) using threat-related objects as distractors found that visual features of threats are easier to suppress than affective features. However, in that study, the presentation of the two features was mixed; i.e., trials with threatening distractors and nonthreatening but visually similar distractors were randomly presented to the participants. This might have caused a generalisation of the threat effect from the real threatening objects to those with the same visual features. Participants who once saw the snake might think that all curvy distractors were snakes. Thus, a strength of our study is that the presentation of the two features was not mixed, i.e., participants only saw threatening or shape-matched neutral distractors but not both. This means that the effect we found could not be caused by a generalisation of the threat value to the visual feature.

Further, we used a visual search paradigm allowing the participants to freely explore the visual scene which made it difficult to interpret the distractor eccentricity (the distance between the target and distractor) (Pakai-Stecina et al., 2024). In the present study, participants fixated on the target appearing in the centre of the screen while distractors appeared at the same time in different eccentricities ensuring that distractors were presented in the fovea, parafovea, or periphery. Consequently, we propose that just the shape of the threatening object can cause the same effect – and, therefore, lack of distraction – relative to neutral stimuli.

In the present study, we focused solely on threatening and non-threatening images without manipulating arousal using other valences such as positive images. This restricts the generalizability of our findings to other types of emotional stimuli. While the assumption of higher arousal and more negative valence for the threat compared to neutral categories is reasonable, we did not measure this directly. There are other differences between threats and their visually similar counterparts that could be relevant, including, for example, knowledge of the threat. The dual implicit process model of evaluation (March et al., 2018) proposes two interconnected automatic mechanisms, in which threat perception influences valence processing, which in turn affects explicit processes like evaluation. While the emotion ("fear") elicited by an object precedes its evaluation ("this is dangerous"), participants saw several representations, so ongoing attentional processes should also be considered. Again, we did not find a difference between threatening and shape-matched nonthreatening distractors suggesting that conscious processes (such as evaluation) play a lesser role in attentional biases towards threats. Given that future studies confirm these findings, this could be an important step towards an understanding of the cognitive mechanisms involved in threat processing and perception as well as the maintenance of specific phobias.

Stimulus eccentricity mostly affected performance in trials with neutral control distractors while it seemingly had no effect in trials with a threat-related distractor. Concerning neutral control stimuli, the results are in line with expectations based on, e.g., the guided search theory (Wolfe, 2021). Stimuli that are closer to fixation are given priority in attentional processing (thus it is harder to inhibit them by top-down control), while distractors appearing further from the task are easier to inhibit (and have considerably smaller effects on task performance). Interestingly, for both threatening and shape-matched nonthreatening distractors the performance remained unchanged across stimulus eccentricities, suggesting that the presence of threat-related information overrides the distance-related variations.

Considering the arousal stimulation effect theory (Zsido et al., 2020, 2021; Zsido, Bernath, et al., 2018) increased levels of arousal elicited by threat-relevant information may compensate for a negative effect of distractors, resulting in overall better performance in the close condition compared to neutral control stimuli. While past research has only demonstrated this effect with threatening stimuli, our results suggest that it is triggered by visual features strongly associated with threats.

Some limitations of the study shall be noted. First, we solely examined behavioural outcomes and did not investigate neural correlates, which could have provided a more comprehensive understanding of the underlying mechanisms. In future directions, our study can be expanded by investigating the neural pathways underlying attentional biases towards threatening stimuli, utilising techniques such as EEG and ERP to explore the temporal dynamics and neural signatures associated with these biases. Second, individual differences such as anxiety and (both objective and subjective) fatigue levels may interact with the arousal and distracting effects of threats. Incorporating measures of anxiety and fatigue would enable direct monitoring of participants' vigilance and anxiety levels during the task and may provide deeper insights into the results.

In conclusion, our findings support the notion that threat information affects attentional processing based on visual features. The effect of threat-related distractors seems to be independent of their distance from the fovea, although they seem to enhance performance on the primary task when presented near it. Understanding this attentional bias towards threat-related information is crucial, as it forms the foundation for the development and persistence of anxiety disorders, including phobias. Targeting the attentional bias associated with threat-relevant features through interventions aimed at reducing fear and anxiety symptoms can have significant implications for improving treatment outcomes (Cisler & Koster, 2010; McNally, 2018).

7. FINAL CONCLUSIONS

The focus of this dissertation is the exploration of the feasibility of inhibiting threatening information conveyed through different means (affective vs. visual features), marking a relatively novel concept. Numerous studies have consistently demonstrated the swift capture of attention by threatening stimuli (Coelho et al., 2019; Mineka & Öhman, 2002; Öhman & Mineka, 2001; Öhman & Soares, 1998; Williams et al., 2006; Zsidó et al., 2017). A long-standing debate in the field questions whether this bias primarily stems from the affective aspects (Fear Module Theory (Mineka & Öhman, 2001)) or the general features (General Feature Detection Theory (Coelho & Purkis, 2009)) of these stimuli. This dissertation introduces another layer to the debate — the Attention Capture Debate (Desdimone & Duncan, 1995; Egeth & Yantis, 1997; van Zoest et al., 2004; Theeuwes, 2010; Gaspelin & Luck, 2017; Luck et al, 2021) — centred around the mechanisms by which physically salient stimuli capture our attention. Theories differ, with some suggesting that salient stimuli inevitably capture attention automatically (stimulus-driven attention), while others propose that these stimuli can be ignored when irrelevant to our goals (goal-driven attention). Results in this domain indicate that various factors may influence the interplay between goal-driven and stimulus-driven processes. Additionally, the Signal Suppression Hypothesis (Sawaki & Luck, 2010) posits that it is possible to suppress the processing of visually salient stimuli before attentional capture occurs.

Through four studies and five experiments, we departed from the conventional methodological approach of investigating the relationship between attention and threat perception (which is, using threatening stimuli as targets) by delving into inhibition, while considering potential confounding factors (e.g., the effect of distractors' distance from the target and the possibility of evoking disgust instead of threat).

Table 7.1 – An overview of the results of experiments presented in the dissertation.

Study nr.	Experiment nr.	Paradigm	Main result
Study I.	Systematic review	Literature review	Stimulus-driven and goal-driven processes interact. Goal-driven processes are more prominent in tasks with a feature search strategy.
	Narrative review	Literature review	Threat has a pronounced impact on attention compared to other emotions. Stimulus-driven and goal-driven processes interact. Introducing hard tasks and top-down goals enhances effective inhibition of threatening distractors.
Study II.	Experiment 1	Visual search task	Inhibiting affective features of threatening information is challenging, regardless of its position inside or outside attentional focus. Shape features are easier to inhibit outside of attentional focus.
	Experiment 2	Addition of eye-tracking	Despite behavioural interference, less fixations happened on threatening distractors, indicating possible active spatial suppression and diversion of cognitive resources from the main task.
Study III.	Experiment 1	Visual search task	Inhibiting affective features of disgusting information is challenging, whether the item is inside or outside the attentional focus. Study II's nonthreatening distractors did not elicit disgust, but it appears that disgust cannot be extracted from our threatening stimuli.
Study IV.	Experiment 1 Replication of Experiment 1	Semantic vigilance task	Threat influences attention based on visual features, with the effect of threat-related distractors independent of their distance from the fovea, enhancing performance on the primary task when presented nearby.

In Study II, we incorporated threatening and nonthreatening shape-similar stimuli as distractors in a visual search task, supporting our investigation with eye-tracking data. The study aimed to assess how these salient, yet task-irrelevant stimuli attract attention in a visual search task and to discern the predominant influence between affective and visual features in attention biasing. Our findings indicate that threatening information provides a robust attention capture, making inhibition near foveation challenging. Threatening information can be rapidly ascertained, requiring minimal stimulus detail in foveal vision – in this case, shape similarity sufficed to induce interference. Even though threatening stimuli induced behavioural interference, participants fixated on them less often. This suggests active spatial suppression of their position, redirecting cognitive resources away from the main task. Visual features of threats only interfered when closer to the focus of attention, with outside positions exhibiting easier inhibition but triggering more orienting eye movements, likely due to rapid dismissal as nonthreatening.

Study III was conducted in response to critiques concerning our nonthreatening but shape-similar distractor (worm) in Study II possibly evoking disgust. The findings suggest that inhibiting affective features of both disgusting and threatening information is challenging, regardless of the item's position within attentional focus. Notably, shape-similar nonthreatening (worm) and disgusting (roach), along with neutral (rabbit) distractors, displayed differences between Study II and III. This supports the notion of shape-conveyed information about threat, challenging the presumption that the behavioural results from Study II's nonthreatening distractors are solely explained by their potential to evoke disgust. Interestingly, this exploration revealed the intricate interconnection between fear and disgust, posing challenges in their separation, especially when using stimuli like snakes. It raises the possibility that our threatening distractor may not be purely threatening but may also evoke disgust.

Conducted as an improved methodological approach, Study IV aimed to investigate the impact of threatening and nonthreatening distractors' distance from the target across two experiments. We conducted a replication study as well, where participants engaged in the same semantic vigilance task as in Experiment 1, except, our distractor categories were expanded. This modification aimed to address concerns from Experiment 1 about the generalizability of our results to a broader range of threats. In conclusion, our results reinforce the idea that threat information influences attentional processing based on visual features. Notably, the effect of threat-related distractors appears to be consistent regardless of their distance from the fovea, enhancing performance on the primary task. This lends support to the General Feature Detection theory (Coelho & Purkis, 2009), over the Fear Module theory (Öhman & Mineka, 2001).

In sum, the primary discovery of the dissertation is the formidable challenge of inhibiting negative stimuli when used as distractors. Similar to physically salient stimuli, the interaction between stimulus- and goal-directed attention is intricate. It appears that the neural and attentional attributes involved in perceiving threatening stimuli are activated solely through visual features. Consistent with previous findings (Zsidó et al., 2022, 2023), we noted that the presentation of threatening stimuli could enhance task performance when in close proximity to the task. Interestingly, we also found a strong association between threat and disgust, although not from the expected non-threatening, shape similar distractor. Study III revealed that it is challenging to exclusively attribute the observed reactions to threat when using stimuli like snakes. An interesting inquiry for future research could involve investigating potential differences between the ambiguous threatening stimuli (e.g. snakes and spiders) and threats that are not associated with disgust (e.g. big cats, bears, sharks, or alligators).

8. LIMITATIONS AND FUTURE PROSPECTS

Our studies have a significant limitation: they are not conducive to modelling everyday life. Instead, their results aim to depict general truths about attentional processes regarding threatening stimuli. As evidenced, isolating attentional processes proves challenging even in controlled laboratory tasks, making it highly improbable in real-world scenarios. Nevertheless, understanding the shortcomings and failures of the attentional system can provide with valuable practical insights across numerous domains. For instance, in certain professions, this understanding can aid in employee screening and training. Moreover, it can contribute to the identification and treatment of attentional system dysfunctions in various conditions such as brain damage, attention deficit disorders, and specific phobias.

Our studies also have methodological limitations. Although as we progressed with the experiments, we tried to address these limitations, they are still worthy of consideration. In Study II and III, participants engaged in a free visual search, allowing for variable foveal positions of special distractors. The task design of Study II, Experiment 2 prohibited a detailed analysis of eye movements, such as the initial saccade destination explored in previous studies (Gaspelin et al., 2017; Hamblin-Frohman et al., 2022), as well as due to a mishap in our data collection, we were unable to replicate the behavioural results of Study II, Experiment 1. Additionally, our use of eye-tracking methodology only captures overt eye movements. Future research should incorporate additional methodologies like EEG or MEG to gain a comprehensive understanding of inhibition processes during covert attention. Therefore, we advocate for replicating our study using alternative techniques.

Furthermore, variations in individual factors such as anxiety and (both objective and subjective) fatigue levels could intersect with the arousal and distracting impacts of threats. In future research, we encourage integrating assessments of anxiety and fatigue, which would allow for the direct tracking of participants' vigilance and anxiety levels throughout the task, potentially yielding deeper insights into the outcomes.

In our examination of threatening and disgusting affective distractors, we initially presumed snakes to be solely threatening stimuli. Yet, our findings revealed notable parallels in the attentional impact of snakes and cockroaches during our experiments. Although snakes are commonly employed in studies on threat perception, our results indicate these stimuli may entail broader implications. This matter calls for further investigation in future research. We advocate for studies comparing threatening stimuli that may also elicit disgust, such as snakes and spiders, with threatening stimuli that do not, such as sharks, bears, tigers, and so forth (Coelho et al., 2023).

9. NEW THESIS OF THE DISSERTATION

I. Interactions Between Stimulus- and Goal-Driven Attentional Processes

Physically and emotionally salient stimuli capture attention in a stimulus-driven manner. While some cases allow for inhibition – aligning with the Signal Suppression Hypothesis (Sawaki & Luck, 2010) – resulting in no behavioural interference, threatening distractors pose a considerable challenge. Despite potential spatial inhibition at greater distances from the target, the effort required leads to observable behavioural interference.

II. The Role of Shape in Attentional Bias and Inhibition

Our studies highlight the potency of shape similarity in triggering attentional bias. While our findings presented conflicting results on this issue throughout our studies, it appears possible that threat-related information could override distance variations in attentional modulation.

III. Insights into Emotional Distractors

Our investigation into threatening and disgusting affective distractors (snake and roach, respectively), revealed striking similarities in their modulation of attention throughout our experiments. While snakes are frequently utilised in threat research, our findings suggest that these stimuli may encompass more than just the perception of threat. This issue should receive more attention in future research.

10. SUPPLEMENTARY MATERIAL

Table 2.1 - Summary of the 14 articles and 33 studies included in our systematic review. The colour of the first cell indicates which theory is supported by the study: blue = stimulus-driven processing advantage, yellow = goal-driven processing/attention control, green = both. Abbreviations: RT = reaction time, ER = error rate, EEP = event evoked potential, AUC = area under the curve, MAD = maximum absolute deviation, RSVP = rapid serial visual presentation, SOA = stimulus onset asynchrony.

Authors	Year	Exp. N.	Participants	Measured variables	Task	Stimuli	Target	Distractors	Results
Burnham et al.	2010	1	N=31	RT, ER	Target detection	After fixation cross, a static cue line consisting of red X and green O appeared on the screen in 3 possible positions. The X’s could predict the position of the target with their different lengths. Then four special character stimuli (e.g. *&#!) appeared in a line (also in 3 possible positions)	”*” and ”&” characters	other special characters (pl. #, @, !)	Subjects found the target faster when it was presented at the location of the static cue line change.
		2A	N=34	RT, ER	Target detection	Same as Exp 1., except the red and green colours have been changed to white	see Exp. 1.	see Exp. 1.	see Exp. 1.
		2B	N=34	RT, ER	Target detection	Same as Exp. 1., except the stimuli were red and green	see Exp. 1.	see Exp. 1.	see Exp. 1.
		3	N=34	RT, ER	Target detection	Same as Exp. 2B, except instead of green O's they used green X's, there is a colour change in the line only	see Exp. 1.	see Exp. 1.	see Exp. 1.
		4	N=31	RT, ER	Target detection	same as Exp. 3., except always the same cue line appeared	see Exp. 1.	see Exp. 1.	see Exp. 1.

Authors	Year	Exp. N.	Participants	Measured variables	Task	Stimuli	Target	Distractors	Results
Carmel & Lamy	2015	1	N=11 (f=11)	RT, ER	Target detection	Detection of the direction of a blue or red letter T in four possible locations on the screen (150ms). Cue was presented (50ms or 150ms) and was followed by ISI (100ms or 0ms). Cue stimulus colour was the same as the target colour in 50% of the time, position was predicted of the target position 25% of the time. In 20% of cases no cue stimulus was presented.	Red or Blue letter T	Different coloured T letters appearing at the same time as the target. Cue stimulus with the same or different colour as the target.	For off-target colour, there is no significant effect of distracting stimuli at 50ms cue presentation, while there is a significant attentional capture at 150ms presentation. For the same colour as the target, attentional capture is significant at both presentation times.
		2	N=14 (m=5, f=9)	RT, ER	Target detection	Same as Exp. 1., but the target was always a lone stimulus, the non-target T letters were the same colour. The contrast of target and non-target T letters was controlled. Cue presentation was 17ms or 50ms.	see Exp. 1.	see Exp. 1.	There was no significant effect of irrelevant colour distractor stimuli with 50ms presentation time. There was a significant effect at 17 ms presentation time, presented at the same location - role of location. For relevant colours, a significant effect was observed at both presentation times.
		3	N=21 (f=21)	RT, ER	Target detection	Same as a Exp. 1. (T letter stimuli of different colours next to the target) and Exp. 2. (identical to the target T letter stimuli of different colours next	see Exp. 1.	see Exp. 1.	Irrelevant coloured distractor stimulus in the same location as the target is a distraction - same location cost, not attentional capture.

Authors	Year	Exp. N.	Participants	Measured variables	Task	Stimuli	Target	Distractors	Results
						to the target). Cue presentation 150 ms.			Contingent attentional capture is no different if the target is a singleton or not. Singleton distractors are more likely to capture attention if the target is also a singleton.
Dieciuc, Roque & Boot	2019	1	N=20 (f=13, m=7)	Trajectory of the cursor from the starting point to the target. AUC and MAD	Target detection on the screen in four possible locations.	Four positions appearing on the screen (500ms), one can display the target. Cue was presented (75ms) in one of the positions (on the same or opposite position as the target)	Green or red X	In one of the four selected locations, there is a cue presented (same colour as target or irrelevant colour).	Participants' cursor trajectories were biased towards cues appearing on opposite sides, but there was no difference in complexity between the trajectories (to the same and opposite sides). Attentional capture was stronger for cues of the same colour. Attentional capture occurs through bottom-up mechanisms.
Gaspelin, Leonard & Luck	2017	1	N=20 (m=4, f=16)	RT, eye movements: first saccade, oculomotor grasp, saccade latency	Target detection	After a 500ms fixation cross, the stimuli appeared. Six stimuli appeared around the fixation cross: five circles and a diamond shape (target) or five diamond shapes and a circle (target). A different colour (red among green stimuli) was presented among the distractors. Lines tilted to the right or left were placed in the middle of the stimuli, and the	Among diamond shapes: circle, among circles: diamond shape	Green coloured shapes and a red coloured shape.	The main distractor had strong oculomotor and behavioural effects. The first saccade fell significantly more often on the singleton.

Authors	Year	Exp. N.	Participants	Measured variables	Task	Stimuli	Target	Distractors	Results
						direction of the line in the target was to be indicated by pressing a button.			
		2	N=20 (m=4, f=16)	see Exp. 1.	Target detection	Same as Exp. 1., except the target was always a circle for half of the participants, while the diamond shape was for the other half. The distractors were randomly generated square, hexagon and circle/diamond shapes (the latter depending on which target group it was presented to). One distractor was always a salient red or green colour.	Circle or diamond shape	Green shapes among red distractors, or vice versa	The task is designed in such a way that it does not support a singleton search strategy. The number of first saccades was reduced for the salient stimuli. However, the long/controlled fixation time before the task may explain this result.
		3	N=20 (m=6, f=14)	see Exp. 1.	Target detection	Same as Exp. 1., only the fixation cross' presentation length was shortened to 100ms and the fixation cross disappeared from the search screen.	see Exp. 1.	see Exp. 1.	Same as Exp. 2., the results support the signal suppression hypothesis.
Lamy, Leber & Egeth	2004	1	N=32	SOA, RT, ER	Spatial cueing task, detecting the location of the target by colour among five distracting stimuli, there was a salient distractor cue presented as well	6 squares were placed around a fixation cross (1000ms), followed by the presentation of the salient distractor stimulus at one of the square locations (50ms), followed by ISI (10, 50, 100 or 200 ms), and finally the target was presented at one of the square locations (50ms)	Red or green stimulus	**Blocks**: **Target colour homogeneous** condition: the salient distractor is the same colour as the target, **non-target-colour condition**: a	Similar attentional capture was observed in the **target-colour homogeneous** and **target-colour heterogeneous** conditions. In the **non-target-colour** condition, inhibition was observed.

Authors	Year	Exp. N.	Participants	Measured variables	Task	Stimuli	Target	Distractors	Results
								salient distractor has a different (salient) colour than the target, **target -colour heterogeneous condition**: salient distractor stimulus contained the target colour; other stimuli are different colours	
		2	N=14	see Exp. 1.	see Exp. 1.	see Exp. 1.	see Exp. 1.	Same, except instead of presentation in blocks, presentation was random	see Exp. 1.
		3	N=24	ER	Detect/identify target letter in RSVP task	RSVP task: presentation of 20 letters in sequence (50ms/letter). The target was randomly positioned, the colour of the distractor letter stimuli differed from the colour of the target letter. Distractors ('#') were presented in 5th, 6th or 7th position, on the peripheries.	Red / green letters	Letters of different colours from the target, presented in a row + 8 '#' characters presented in a circle, they were the same	When **heterogeneous** distractors were presented, and the target colour appeared, target detection was disrupted if the distractor appeared 2-5 stimuli before the target. In the **homogeneous** condition, attentional capture was significant

Authors	Year	Exp. N.	Participants	Measured variables	Task	Stimuli	Target	Distractors	Results
								colour or a different colour than the target. In **homogeneous** condition all '#' are the same colour, in **heterogeneous** condition they are different colours.	even 1 stimulus before the target presentation. No attentional capture was observed for **non-target coloured** distractors.
Livingstone et al.	2017	1	N=40 (m=14, f=26)	RT, EEP: N2pc, Pd, CP components	Target detection	Same as **Sawaki & Luck's (2013)** study, except the grey circle cues were omitted. **Condition 1**: the stimuli were standardized by luminance. **Condition 2**: stimuli were not standardized by luminance There was a 100, 200 or 300 ms pause between the cue and the search screen by random presentation (fixation cross only)	Same, as Sawaki & Luck (2013)	Same, as Sawaki & Luck (2013)	Cue-induced processing (CP) is not limited to the cue screen, but extends to the search screen, even if the target appears in the same or a different location. CP indicates enhanced processing of the stimulus in the same location during the stage of visual processing that precedes attentional selection. In **congruent trials**, the processing of the target is enhanced, whereas in **incongruent** trials the processing of the distractor is enhanced at the cue location. Increased processing of the distractor

Authors	**Year**	**Exp. N.**	**Participants**	**Measured variables**	**Task**	**Stimuli**	**Target**	**Distractors**	**Results**
									creates a competitive situation in finding the target, which takes longer to resolve.
Mast & Frings	2014	1	N=31 (m=3, f=28)	RT, ER	Detection of the colour of the second stimulus on the screen.	Two stimuli were presented in succession after fixation cross. The stimuli are red and green squares. The first stimulus appears in the centre or edge of the screen, the second stimulus appears in the centre of the screen.	Green or red square	Square of the same or opposite colour appearing in front of the target	The more matching characteristics there are between the cue and the target, the worse the subjects performed (incongruent, colour, location and colour.)
		2	N=24 (m=8 f=16)	RT, ER	Detection of the shape of the second stimulus on the screen. In all cases, the colour of the stimulus is green	Same as Exp. 1., except the shape of the stimuli is different: it is either circle or square. Cue and target were always presented in the same place (center of screen).	Green circle or square	Circle or square, they could be green or of different colour	see Exp. 1.
		3	N=32 (m=6, f=26)	RT, ER	see Exp. 1.	Same as Exp 1., except the cue was followed by a 40ms mask, reducing its visibility	see Exp. 1.	see Exp. 1.	see Exp. 1.
Parkhurst, Law & Niebur	2002	1	N=4 (m=2, f=2)	Eye movements	Free observation of the images presented	Presentation of images in 4 categories (interiors, nature, cityscapes, fractals), 25 images presented in each category (5s/image)	Examination of natural eye movements in unattended viewing conditions. It was hypothesised that bottom-up processing would result in more fixation in the salient regions of the images.		The first fixations are significantly more often directed to the salient areas. Further fixations also occurred more on salient areas. Under normal viewing conditions, without task, eye movements were stimulus-driven.

Authors	Year	Exp. N.	Participants	Measured variables	Task	Stimuli	Target	Distractors	Results
Sawaki & Luck	2010	1	N=12	RT, ER EEP: N2pc, Pd components	Target detection	A series of small and large letters (A, H, I, M, O, T, U, X, Y) (2-2 small and large letters/area) were presented in the top and bottom of the visual space. In the task, subjects were asked to focus only on the lower OR upper visual space, maintaining central fixation. They were required to respond to the target by pressing a button only in the selected area, ignoring the non-observed area. In the first condition, all letters were green or red. In the second condition, a pop-out red distractor stimulus was present among the other (green) stimuli.	Small or large selected letter	Several small or large letters, and in the second condition, a letter of a salient colour	The observed area showed an increased false alarm response for distractors similar to the target. In the unobserved area for the salient stimuli, the rate of false alarms was low. N2pc components were elicited by the target and similar distractors only in the observed area. Pd component was elicited by the salient stimuli in both areas, suggesting attentional inhibition.
		2	N=12	see Exp. 1.	Target detection	Same as Exp. 1., except both visual spaces had to be observed by the subjects.	see Exp. 1.	see Exp. 1.	see Exp. 1.
		3	N=12	see Exp. 1.	Target detection	Same as Exp. 1., except four squares were shown around the fixation cross, three missing the left or right side and one missing the top or bottom	Square with the top or bottom missing.	Squares with missing sides + letters as in the previous experiments.	Test subjects could ignore the distractor letters. A smaller Pd component was measured than in previous studies.
		4	N=12	see Exp. 1.	Target detection	Same as Exp. 2., except in half the trials all stimuli were red except for the distractor, which was green. In the other half of	See Exp. 2.	See Exp. 2.	Only distractors similar to the target elicited higher false alarm rates.

Authors	Year	Exp. N.	Participants	Measured variables	Task	Stimuli	Target	Distractors	Results
						the trials the colours were reversed. Trials were presented in blocked random order.			Pd component was significantly higher for the salient distractors. N2pc component was significant for target and distractors similar to the target.
Sawaki & Luck	2013	1	N=12 (m=4, f=8)	RT, EEP: N2pc, Pd components	Target detection	On a cue screen, four coloured (80% of cases) or four grey (20% of cases) circles were presented around a fixation cross. Subjects were instructed to ignore the cue stimuli. One of the coloured cue stimuli was the same colour as the target, but its position did not predict the location of the target.	Three-sided square of selected colour, the task was to indicate by pressing a button whether the bottom or top side of the square was missing.	Coloured/grey circle cue stimuli, one of which matched the colour of the target but did not predict its position, and three three-sided squares of a different colour from the target.	A cue stimulus of the same colour as the target attracted attention (indicated by both behavioural and ERP (N2pc component) measures). Attentional capture was followed by active inhibition (ERP: Pd component) and then attention was redirected to the target. Thus, involuntary attentional capture was followed by active inhibition and volitional orientation.
Schreij et al.	2014	1	N=14	RT, latency of first saccade	Target detection in four possible locations on the screen	There were four locations around the fixation cross where the target could appear (500ms). After the presentation of a cue at one locations (50ms), the detection of the target followed after fixation (100ms) (until response)	Red letter	**Two types: irrelevant red cue** presented before (25% of the time, it matches the location of the target), **irrelevant white**	Participants were slowed down by the irrelevant distractor appearing at the same time as the target, even if the cue predicted the location of the target. In the same way, the incongruent cue slowed RTs. The effects of the two

Authors	**Year**	**Exp. N.**	**Participants**	**Measured variables**	**Task**	**Stimuli**	**Target**	**Distractors**	**Results**
								distractor presented with the target (50% of the time)	types of distractors interacted with each other and determined the position of the first and second saccades. The distractors capture spatial attention.
Schubö	2009	1	N=16 (m=4, f=12)	RT, ER, EEP: N1, posterior N2, N2pc	Target finger detection at 8 possible locations	The screen shows 8 shapes placed around a fixation cross, the direction of the lines within the shapes must be detected. In the **target-only condition**, the target is of a different colour or shape to the other stimuli. In the **target-distractor condition**, a salient distractor stimulus appears in addition to the target. If the target is a different colour, the distractor is a different shape. If the target is a different shape, the distractor is a different colour. The two conditions were presented in two blocks.	Salient coloured or salient shaped stimulus	Salient coloured or salient shaped stimulus	RT was slower when an irrelevant distractor stimulus was presented. This effect was larger when the target was a different shape, and the salient distractor was a different colour. The coloured singleton stimulus generated a larger bottom-up signal. According to differences in N1 and N2 latencies, in the **target-only condition** spatial attention is more concentrated (higher N1 negativity). In the **target-distractor condition**, spatial attention is more distributed. Higher N2 negativity was also observed in the **target-only condition**, which may indicate a singleton selection strategy.

Authors	Year	Exp. N.	Participants	Measured variables	Task	Stimuli	Target	Distractors	Results
									N2pc component did not differ between the two conditions when coloured targets were searched. In the **shape-target condition,** the N2pc magnitude decreased depending on the position of the differently coloured distractor. The colour distractor had a stronger attentional grip.
Stilwell & Gaspelin	2021	1	N=24 (m=3, f=21)	RT	Target detection, recalling letters	On each search screen, 10 green stimuli (different shapes: circle, diamond, oval, hexagon, etc.) were presented, arranged around a fixation cross. **Condition 1**: subjects had to indicate the position of a black dot inside the target (right or left) **Condition 2**: white letters (4 or 10) were placed in the shapes (100ms) and then they were masked (#) (500ms). Subjects had to recall the letters. The number of letters was randomized during the trials.	**Condition 1**: target shape and position of the dot inside (left or right) **Condition 2**: white letters appearing in the shapes	A red shape among green shapes	The salient distractor had no effect on RTs or the number of letters recalled. However, participants recalled the letter presented in the salient distractor significantly less often. The singleton stimulus was proactively inhibited by subjects. However, both the recall accuracy and the inhibition effect were lower in the 10-letter arrangement.
		2	N=24 (m=10, f=14)	RT	see Exp. 1.	Same as Exp. 1., except the number of stimuli presented was increased to 30, the stimuli were placed in two circles. 10	see Exp. 1.	see Exp. 1.	see Exp. 1.

Authors	Year	Exp. N.	Participants	Measured variables	Task	Stimuli	Target	Distractors	Results
						shapes were presented in the inner circle and 20 in the outer circle. The target and the salient distractor were not shown in the outer circle, nor were the letters. (The purpose of the outer circle was to increase the salient distractor's salience.)			
		3	N=24 (m=10, f=14)	RT	see Exp. 1.	Same as Exp. 1., except the shapes were not filled, they were only outlines presented on a grey background.	see Exp. 1.	see Exp. 1.	RT was faster in the trials, where the salient distractor was also present.
		4	N=40 (m=13, f=27)	RT	see Exp. 1.	Same as Exp. 3., except the mask was removed (#).	see Exp. 1.	see Exp. 1.	RT was slower when the salient distractor was present. Inhibition of the salient distractor was stronger when 4 letters were presented than when 10 letters were presented.
Wang & Theeuwes	2020	1	N=72 (f=64, m=8)	RT, ER	Target detection at 4, 6 or 10 possible locations	4, 6 or 10 shapes were arranged in a circle around a fixation cross, one of them of different colours.	Circle / diamond shape	Different (red or green) shape	**Four shapes**: there is no difference in RTs between the distractor and no-distractor trials. **Six shapes**: significantly slower RT when the distractor is present compared to when it is absent. **Ten shapes**: increasing significance between the two conditions

Authors	Year	Exp. N.	Participants	Measured variables	Task	Stimuli	Target	Distractors	Results
		2	N=72 (f=64, m=8)	number of letters recalled	Memorizing and recalling letters	4, 6 or 10 shapes were arranged in a circle around a fixation cross, one of which is a different colour. Letters were presented inside of the shapes	Letter presented inside of the shapes	see Exp. 1.	**Four shapes**: significantly more letters were recalled by subjects from shapes with not salient colour than vice versa. **Six shapes**: no significant differences. **Ten shapes**: more letters were recalled from shapes with a salient colour.

11. REFERENCES

Almeida, I., Soares, S. C., & Castelo-Branco, M. (2015). The distinct role of the amygdala, superior colliculus and pulvinar in processing of central and peripheral snakes. *PLoS ONE*, 10(6). https://doi.org/10.1371/journal.pone.0129949

Anderson, B. A., & Kim, H. (2019). On the relationship between value-driven and stimulus-driven attentional capture. *Attention, Perception, and Psychophysics*, 81(3), 607–613. https://doi.org/10.3758/s13414-019-01670-2

Bayle, D. J., Henaff, M. A., & Krolak-Salmon, P. (2009). Unconsciously perceived fear in peripheral vision alerts the limbic system: A MEG study. *PLoS ONE*, 4(12), e8207. https://doi.org/10.1371/journal.pone.0008207

Becker, D. V., Anderson, U. S., Mortensen, C. R., Neufeld, S. L., & Neel, R. (2011). The face in the crowd effect unconfounded: happy faces, not angry faces, are more efficiently detected in single- and multiple-target visual search tasks. *Journal of Experimental Psychology: General*, 140(4), 637–659. https://doi.org/10.1037/a0024060

Berggren, N. (2022). Rapid attentional biases to threat-associated visual features: the roles of anxiety and visual working memory access. *Emotion*, 22(3), 545–553. https://doi.org/10.1037/emo0000761

Birkás, B., Kiss, B., Coelho, C. M., & Zsidó, A. N. (2023). The role of self-reported fear and disgust in the activation of behavioural harm avoidance related to medical settings. *Frontiers in Psychiatry*, 14(4). https://doi.org/10.3389/fpsyt.2023.1074370

Blanchette, I. (2006). Snakes, spiders, guns, and syringes: How specific are evolutionary constraints on the detection of threatening stimuli? *Quarterly Journal of Experimental Psychology*, 59(8), 1484–1504. https://doi.org/10.1080/02724980543000204

Bradley, M. M., Hamby, S., Löw, A., & Lang, P. J. (2007). Brain potentials in perception: Picture complexity and emotional arousal. *Psychophysiology*, 44(3), 364–373. https://doi.org/10.1111/j.1469-8986.2007.00520.x

Brady, T. F., Konkle, T., Alvarez, G. A., & Oliva, A. (2008). Visual long-term memory has a massive storage capacity for object details. *Proceedings of the National Academy of Sciences of the United States of America*, 105(38), 14325–14329. https://doi.org/10.1073/pnas.0803390105

Brosch, T., & Sharma, D. (2005). The role of fear-relevant stimuli in visual search: a comparison of phylogenetic and ontogenetic stimuli. *Emotion*, 5(3), 360–364. https://doi.org/10.1037/1528-3542.5.3.360

Brown, C., El-Deredy, W., & Blanchette, I. (2010). Attentional modulation of visual-evoked potentials by threat: Investigating the effect of evolutionary relevance. *Brain and Cognition*, 74(3), 281–287. https://doi.org/10.1016/J.BANDC.2010.08.008

Brown, C. R. H., Berggren, N., & Forster, S. (2020). Testing a goal-driven account of involuntary attentional capture by threat Chris. *Emotion*, 20(4), 572–589.

Burnham, B. R., Neely, J. H., Naginsky, Y., Thomas, M. (2010). Stimulus-driven attentional capture by a static discontinuity between perceptual groups. *Journal of Experimental Psychology: Human Perception and Performance*, 36(2), 317–329. https://doi.org/10.1037/a0015871

Burra, N., Coll, S. Y., Barras, C., & Kerzel, D. (2017). Electrophysiological evidence for attentional capture by irrelevant angry facial expressions: Naturalistic faces. *Neuroscience Letters*, 637, 44–49. https://doi.org/10.1016/j.neulet.2016.11.055

Burra, N., Pittet, C., Barras, C., & Kerzel, D. (2019). Attentional suppression is delayed for threatening distractors. *Visual Cognition*, 27(3–4), 185–198. https://doi.org/10.1080/13506285.2019.1593272

Cacioppo, J. T., & Berntson, G. G. (1999). The affect system: Architecture and operating characteristics. *Current directions in psychological science*, *8*(5), 133-137.

Calvo, M. G., & Lang, P. J. (2005). Parafoveal semantic processing of emotional visual scenes. *Journal of Experimental Psychology: Human Perception and Performance*, 31(3), 502–519. https://doi.org/10.1037/0096-1523.31.3.502

Calvo, M. G., Nummenmaa, L., & Hyönä, J. (2008). Emotional scenes in peripheral vision: selective orienting and gist processing, but not content identification. *Emotion*, 8(1), 68–80. https://doi.org/10.1037/1528-3542.8.1.68

Carmel, T., Lamy, D., Carmel, T., Lamy, D. (2015). Towards a resolution of the attentional-capture debate towards a resolution of the attentional-capture debate. *Journal of Experimental Psychology: Human Perception and Performance*, 41(6), 1772-1782

Carretié, L., Ruiz-Padial, E., López-Martín, S., & Albert, J. (2011). Decomposing unpleasantness: Differential exogenous attention to disgusting and fearful stimuli. *Biological Psychology*, 86(3), 247–253. https://doi.org/10.1016/j.biopsycho.2010.12.005

Carretié, L., Kessel, D., García-Rubio, M. J., Giménez-Fernández, T., Hoyos, S., & Hernández-Lorca, M. (2017). Magnocellular bias in exogenous attention to biologically salient stimuli as revealed by manipulating their luminosity and colour. *Journal of Cognitive Neuroscience*, 29(10), 1699–1711. https://doi.org/10.1162/jocn_a_01148

Cartwright-Finch, U., & Lavie, N. (2007). The role of perceptual load in inattentional blindness. *Cognition*, 102(3), 321–340. https://doi.org/10.1016/j.cognition.2006.01.002

Chapman, H. A., Johannes, K., Poppenk, J. L., Moscovitch, M., & Anderson, A. K. (2013). Evidence for the differential salience of disgust and fear in episodic memory. *Journal of Experimental Psychology: General*, 142(4), 1100–1112. https://doi.org/10.1037/a0030503

Charash, M., McKay, D., & Dipaolo, N. (2006). Implicit attention bias for disgust. *Anxiety, Stress and Coping*, 19(4), 353–364. https://doi.org/10.1080/10615800601055915

Cinq-Mars, J., Blumenthal, A., Grund, A., Hétu, S., & Blanchette, I. (2022). DLPFC controls the rapid neural response to visual threat: An ERP and rTMS study. *Brain Research*, 1784, 147850. https://doi.org/10.1016/j.brainres.2022.147850

Cisler, J. M., & Koster, E. H. W. (2010). Mechanisms of attentional biases towards threat in anxiety disorders: An integrative review. *Clinical Psychology Review*, 30(2), 203–216. https://doi.org/10.1016/J.CPR.2009.11.003

Coelho, C. M., & Purkis, H. (2009). The origins of specific phobias: Influential theories and current perspectives. *Review of General Psychology*, 13(4), 335–348. https://doi.org/10.1037/a0017759

Coelho, C. M., Suttiwan, P., Faiz, A. M., Ferreira-Santos, F., & Zsido, A. N. (2019). Are humans prepared to detect, fear, and avoid snakes? The mismatch between laboratory and ecological evidence. *Frontiers in Psychology*, 10(SEP), 2094. https://doi.org/10.3389/fpsyg.2019.02094

Coelho, C. M., Araújo, A. A. S., Suttiwan, P., & Zsido, A. N. (2023). An ethologically based view into human fear. *Neuroscience and Biobehavioural Reviews*, 145(December). https://doi.org/10.1016/j.neubiorev.2022.105017

Csathó, Á., Tey, F., & Davis, G. (2008). Threat perception and targeting: The brainstem–amygdala–cortex alarm system in action? *Cognitive Neuropsychology*, 25(7–8), 1039–1064. https://doi.org/10.1080/02643290801996360

Czigler, I., Winkler, I., Pató, L., Várnagy, A., Weisz, J., & Balázs, L. (2006). Visual temporal window of integration as revealed by the visual mismatch negativity event-related potential to stimulus omissions. *Brain research*, 1104(1), 129-140.

Czigler, I., Sulykos, I., & Kecskés-Kovács, K. (2014). Asymmetry of automatic change detection shown by the visual mismatch negativity: An additional feature is identified faster than missing features. *Cognitive, Affective & Behavioural Neuroscience*, 14, 278-285.

Czigler, I. (2022). Előhang a kísérleti pszichológiához. *Magyar Pszichológiai Szemle*, 76(3-4), 601-625.

Darwin, C. (1965). The expression of the emotions in man and animals. Chicago: University of Chicago Press. (Original work published in 1872)

Davey, G. C. (1994a). Self-reported fears to common indigenous animals in an adult UK population: The role of disgust sensitivity. *British Journal of Psychology*, *85*(4), 541-554.

Davey, G. C. (1994b). The "disgusting" spider: The role of disease and illness in the perpetuation of fear of spiders. *Society and Animals*, 2(1), 17–25. https://doi.org/10.1163/156853094X00045

Davey, G. C. L. (1995). Preparedness and phobias: Specific evolved associations or a generalized expectancy bias? *Behavioural and Brain Sciences*, 18(02), 289. https://doi.org/10.1017/S0140525X00038498

Davey, G. C. L. (2011). Disgust: The disease-avoidance emotion and its dysfunctions. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 366(1583), 3453–3465. https://doi.org/10.1098/rstb.2011.0039

De Cesarei, A., & Codispoti, M. (2008). Fuzzy picture processing: Effects of size reduction and blurring on emotional processing. *Emotion*, 8(3), 352–363. https://doi.org/10.1037/1528-3542.8.3.352

De Jong, P.J. and P. Muris (2002) 'Spider phobia: Interaction of disgust and perceived likelihood of involuntary physical contact', *Anxiety Disorders* 16: 51–65.

Desimone, R., Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual Review of Neuroscience*, 18, 193–222. https://doi.org/10.1146/annurev-psych-122414-033400

Dieciuc, M. A., Roque, N. A., Boot, W. R. (2019). The spatial dynamics of mouse-tracking reveal that attention capture is stimulus-driven rather than contingent upon top-down goals. *Journal of Experimental Psychology: Human Perception and Performance*, 45(10), 1285–1290. https://doi.org/10.1037/xhp0000671.The

Duncan, J., Humphreys, G. W. (1989). Visual search and stimulus similarity: The efficiency of visual selection. *Psychological Review*, 96(3), 433–458.

Egeth, H. E., Yantis, S. (1997). Visual attention: Control, representation, and time course. *Annual Review of Psychology*, 48, 269–297.

Eimer, M., & Kiss, M. (2007). Attentional capture by task-irrelevant fearful faces is revealed by the N2pc component. *Biological Psychology*, 74(1), 108–112. https://doi.org/10.1016/j.biopsycho.2006.06.008

Ekman, P., & Friesen, W. V. (1971). Constants across cultures in the face and emotion. *Journal of personality and social psychology*, *17*(2), 124.

Ekman, P., Sorenson, E. R., & Friesen, W. V. (1969). Pan-cultural elements in facial displays of emotion. *Science*, *164*(3875), 86-88.

Epling, S. L., Russell, P. N., & Helton, W. S. (2016). A new semantic vigilance task: vigilance decrement, workload, and sensitivity to dual-task costs. *Experimental Brain Research*, 234(1), 133–139. https://doi.org/10.1007/s00221-015-4444-0

Fenker, D. B., Heipertz, D., Boehler, C. N., Schoenfeld, M. A., Noesselt, T., Heinze, H. J., Duezel, E., & Hopf, J. M. (2010). Mandatory processing of irrelevant fearful face features in visual search. *Journal of Cognitive Neuroscience*, 22(12), 2926–2938. https://doi.org/10.1162/jocn.2009.21340

Fink-Lamotte, J., Svensson, F., Schmitz, J., & Exner, C. (2022). Are you looking or looking away? Visual exploration and avoidance of disgust-and fear-stimuli: An eye-tracking study. *Emotion*, *22*(8), 1909.

Folk, C. L., Remington, R. W., Johnston, J. C. (1992). Involuntary Covert Orienting Is Contingent on Attentional Control Settings. *Journal of Experimental Psychology: Human Perception and Performance*, 18(4), 1030–1044. https://doi.org/10.1037/0096-1523.18.4.1030

Forster, K. I. (1970). Visual perception of rapidly presented word sequences of varying complexity. Perception & psychophysics, 8, 215-221.

Fox, E., Russo, R., Bowles, R., & Dutton, K. (2001). Do threatening stimuli draw or hold visual attention in subclinical anxiety? *Journal of Experimental Psychology: General*, 130(4), 681–700. http://www.ncbi.nlm.nih.gov/pubmed/11757875

Fox, E., Russo, R., & Georgiou, G. A. (2005). Anxiety modulates the degree of attentive resources required to process emotional faces. Cognitive, *Affective and Behavioural Neuroscience*, 5(4), 396–404. https://doi.org/10.3758/CABN.5.4.396

Fox, E., Griggs, L., & Mouchlianitis, E. (2007). The detection of fear-relevant stimuli: Are guns noticed as quickly as snakes? *Emotion*, 7(4), 691–696. https://doi.org/10.1037/1528-3542.7.4.691

Gao, X., LoBue, V., Irving, J., & Harvey, T. (2017). The effect of spatial frequency information and visual similarity in threat detection. *Cognition and Emotion*, 31(5), 912–922. https://doi.org/10.1080/02699931.2016.1180280

Gaspelin, N., Leonard, C. J., Luck, S. J. (2017). Suppression of overt attentional capture by salient-but-irrelevant colour singletons. *Attention, Perception, and Psychophysics*, 79(1), 45–62. https://doi.org/10.3758/s13414-016-1209-1

Gaspelin, N., Luck, S. J. (2018a). Distinguishing among potential mechanisms of singleton suppression. *Journal of Experimental Psychology: Human Perception and Performance*, 44(4), 626–644. https://doi.org/https://doi.org/10.1037/xhp0000484

Gaspelin, N., Luck, S. J. (2018b). The role of inhibition in avoiding distraction by salient stimuli. *Trends in Cognitive Sciences*, 22, 79-92.

Goulden, N., Khusnulina, A., Davis, N. J., Bracewell, R. M., Bokde, A. L., McNulty, J. P., & Mullins, P. G. (2014). The salience network is responsible for switching between the default mode network and the central executive network: Replication from DCM. *NeuroImage*, 99, 180–190. https://doi.org/10.1016/j.neuroimage.2014.05.052

Gu, Y., Piper, W. T., Branigan, L. A., Vazey, E. M., Aston-Jones, G., Lin, L., LeDoux, J. E., & Sears, R. M. (2020). A brainstem-central amygdala circuit underlies defensive responses to learned threats. *Molecular Psychiatry*, 25(3), 640–654. https://doi.org/10.1038/s41380-019-0599-6

Hamblin-Frohman, Z., Chang, S., Egeth, H., & Becker, S. I. (2022). Eye movements reveal the contributions of early and late processes of enhancement and suppression to the guidance of visual search. *Attention, Perception, and Psychophysics*, 84(6), 1913–1924. https://doi.org/10.3758/s13414-022-02536-w

Hedger, N., Gray, K. L. H., Garner, M., & Adams, W. J. (2016). Are visual threats prioritized without awareness? A critical review and meta-analysis involving 3 behavioural paradigms and 2696 observers. *Psychological Bulletin*, 142(9), 934–968. https://doi.org/10.1037/bul0000054

Hickey, C., Di Lollo, V., & McDonald, J. J. (2009). Electrophysiological indices of target and distractor processing in visual search. *Journal of Cognitive Neuroscience*, 21, 760-775.

Holmes, A., Mogg, K., De Fockert, J., Nielsen, M. K., & Bradley, B. P. (2014). Electrophysiological evidence for greater attention to threat when cognitive control resources are depleted. *Cognitive, Affective and Behavioural Neuroscience*, 14(2), 827–835. https://doi.org/10.3758/s13415-013-0212-4

Hout, M. C., & Goldinger, S. D. (2010). Learning in repeated visual search. *Attention, Perception, and Psychophysics*, 72(5), 1267–1282. https://doi.org/10.3758/APP.72.5.1267

Hout, M. C., & Goldinger, S. D. (2012). Incidental learning speeds visual search by lowering response thresholds, not by improving efficiency: Evidence from eye movements. *Journal of Experimental Psychology: Human Perception and Performance*, 38(1), 90. https://doi.org/10.1037/A0023894

Hout, M. C., & Goldinger, S. D. (2014). Target templates: the precision of mental representations affects attentional guidance and decision-making in visual search. *Attention, Perception, and Psychophysics*, 77(1), 128–149. https://doi.org/10.3758/s13414-014-0764-6

Hout, M. C., Goldinger, S. D., & Brady, K. J. (2014). MM-MDS: A multidimensional scaling database with similarity ratings for 240 object categories from the massive memory picture database. *PLoS ONE*, 9(11), e112644. https://doi.org/10.1371/journal.pone.0112644

Hout, M. C., Walenchok, S. C., Goldinger, S. D., & Wolfe, J. M. (2015). Failures of perception in the low-prevalence effect: Evidence from active and passive visual search. Journal of Experimental Psychology. *Human Perception and Performance*, 41(4), 977–994. https://doi.org/10.1037/xhp0000053

Humphrey, K., Underwood, G., & Lambert, T. (2012). Salience of the lambs: A test of the saliency map hypothesis with pictures of emotive objects. *Journal of vision*, *12*(1), 22-22.

Hung, Y., Smith, M. Lou, Bayle, D. J., Mills, T., Cheyne, D., & Taylor, M. J. (2010). Unattended emotional faces elicit early lateralized amygdala-frontal and fusiform activations. *NeuroImage*, 50(2), 727–733. https://doi.org/10.1016/j.neuroimage.2009.12.093

Hwang, A. D., Higgins, E. C., Pomplun, M. (2009). A model of top-down attentional control during visual search in complex scenes. *Journal of Vision*, 9(5), 1–18. https://doi.org/10.1167/9.5.25

Jamovi Project. (2022). Jamovi (Version 2.3 for Windows). https://www.jamovi.org

Katsuki, F., Constantinidis, C. (2013). Bottom-up and top-down attention. *The Neuroscientist*, 20(5), 509–521. https://doi.org/10.1177/1073858413514136

Kiss, B. L., Birkás, B., Zilahi, L., & Zsido, A. N. (2022). The role of fear, disgust, and relevant experience in the assessment of stimuli associated with blood-injury-injection phobia. *Heliyon*, 8(12). https://doi.org/10.1016/j.heliyon.2022.e11839

Koster, E. H. W., Crombez, G., Verschuere, B., & De Houwer, J. (2006). Attention to threat in anxiety-prone individuals: mechanisms underlying attentional bias. *Cognitive Therapy and Research*, 30(5), 635–643. https://doi.org/10.1007/s10608-006-9042-9

Koster, E. H. W., Crombez, G., Verschuere, B., Van Damme, S., & Wiersema, J. R. (2006). Components of attentional bias to threat in high trait anxiety: Facilitated engagement, impaired disengagement, and attentional avoidance. *Behaviour Research and Therapy*, 44(12), 1757–1771. https://doi.org/10.1016/J.BRAT.2005.12.011

Krusemark, E. A., & Li, W. (2011). Do all threats work the same way? Divergent effects of fear and disgust on sensory perception and attention. *Journal of Neuroscience*, 31(9), 3429–3434. https://doi.org/10.1523/JNEUROSCI.4394-10.2011

Lamy, D., Leber, A., Egeth, H. E. (2004). Effects of task relevance and stimulus-driven salience in feature-search mode. *Journal of Experimental Psychology: Human Perception and Performance*, 30(6), 1019–1031. https://doi.org/10.1037/0096-1523.30.6.1019

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1999). International affective picture system (IAPS): Instruction manual and affective ratings (Tech. Rep. No. A-4). Gainesville, FL: University of Florida, The Centre for Research in Psychophysiology.

Larson, C. L., Aronoff, J., & Stearns, J. J. (2007). The shape of threat: simple geometric forms evoke rapid and sustained capture of attention. *Emotion*, 7(3), 526–534. https://doi.org/10.1037/1528-3542.7.3.526

Larson, C. L., Aronoff, J., Sarinopoulos, I. C., & Zhu, D. C. (2009). Recognizing threat: A simple geometric shape activates neural circuitry for threat detection. *Journal of Cognitive Neuroscience*, 21(8), 1523–1535. https://doi.org/10.1162/jocn.2009.21111

Lavie, N. (1995). Perceptual load as a necessary condition for selective attention. *Journal of Experimental Psychology: Human perception and performance*, *21*(3), 451.

Lavie, N., & Fox, E. (2000). The role of perceptual load in negative priming. *Journal of Experimental Psychology: Human Perception and Performance*, *26*(3), 1038.

Le Pelley, M. E., Seabrooke, T., Kennedy, B. L., Pearson, D., & Most, S. B. (2017). Miss it and miss out: Counterproductive nonspatial attentional capture by task-irrelevant, value-related stimuli. *Attention, Perception, and Psychophysics*, 79(6), 1628–1642. https://doi.org/10.3758/s13414-017-1346-1

LeDoux, J. E. (1994/a). Emotion, memory and the brain. *Scientific American*, *270*(6), 50-57.

LeDoux, J. E. (1994/b). The amygdala: contributions to fear and stress. In *Seminars in Neuroscience* (Vol. 6, No. 4, pp. 231-237). Academic Press.

LeDoux, J. E. (2000/a). Emotion circuits in the brain. *Annual Review of Neuroscience*, 155–184.

LeDoux, J. (2000/b). The amygdala and emotion: a view through fear. *The amygdala*, 289-310.

LeDoux, J. (2012). Rethinking the Emotional Brain. *Neuron*, 73(4), 653–676. https://doi.org/10.1016/j.neuron.2012.02.004

LeDoux, J. E. (2014). Coming to terms with fear. *Proceedings of the National Academy of Sciences*, *111*(8), 2871-2878.

LeDoux, J. E. (2022). As soon as there was life, there was danger: the deep history of survival behaviours and the shallower history of consciousness. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, 377(1844), 20210292. https://doi.org/10.1098/rstb.2021.0292

LeDoux, J. E., Cicchetti, P., Xagoraris, A., & Romanski, L. M. (1990). The lateral amygdaloid nucleus: sensory interface of the amygdala in fear conditioning. *Journal of neuroscience*, *10*(4), 1062-1069.

Liddell, B. J., Brown, K. J., Kemp, A. H., Barton, M. J., Das, P., Peduto, A., Gordon, E., & Williams, L. M. (2005). A direct brainstem–amygdala–cortical 'alarm' system for subliminal signals of fear. *NeuroImage*, 24(1), 235–243. https://doi.org/10.1016/J.NEUROIMAGE.2004.08.016

Liesefeld, H. R., & Janczyk, M. (2019). Combining speed and accuracy to control for speed-accuracy trade-offs. *Behaviour Research Methods*, 51(1), 40–60. https://doi.org/10.3758/s13428-018-1076-x

Livingstone, A. C., Christie, G. J., Wright, R. D., McDonald, J. J. (2017). Signal enhancement, not active suppression, follows the contingent capture of visual attention. *Journal of Experimental Psychology: Human Perception and Performance*, 43(2), 219–224. https://doi.org/10.1037/xhp0000339

LoBue, V., & DeLoache, J. S. (2008). Detecting the snake in the grass: Attention to fear-relevant stimuli by adults and young children. *Psychological Science*, 19(3), 284–289. https://doi.org/10.1111/j.1467-9280.2008.02081.x

LoBue, V. (2010). And along came a spider: An attentional bias for the detection of spiders in young children and adults. *Journal of Experimental Child Psychology*, 107(1), 59–66. https://doi.org/10.1016/J.JECP.2010.04.005

LoBue, V. (2014). Deconstructing the snake: The relative roles of perception, cognition, and emotion on threat detection. *Emotion*, 14(4), 701–711. https://doi.org/10.1037/a0035898

LoBue, V., Matthews, K., Harvey, T., & Stark, S. L. (2014). What accounts for the rapid detection of threat? Evidence for an advantage in perceptual and behavioural responding from eye movements. *Emotion*, 14(4), 816–823. https://doi.org/10.1037/a0035869

Lowe, R., Humphries, M., & Ziemke, T. (2009). The dual-route hypothesis: evaluating a neurocomputational model of fear conditioning in rats. Connection Science, 21(1), 15–37. https://doi.org/10.1080/09540090802414085

Luck, S. J., & Hillyard, S. A. (1990). Electrophysiological evidence for parallel and serial processing during visual search. *Perception & psychophysics*, *48*(6), 603-617.

Luck, S. J., Hillyard, S. A. (1994). Electrophysiological correlates of feature analysis during visual search. *Psychophysiology*, 31(3), 291–308. https://doi.org/10.1111/j.1469-8986.1994.tb022 18.x.

Luck, S. J., Gaspelin, N., Folk, C. L., Remington, R. W., Theeuwes, J. (2021). Progress toward resolving the attentional capture debate. *Visual Cognition*, 29(1), 1–21. https://doi.org/10.1080/13506285.2020.1848949

Mancini, C., Falciati, L., Maioli, C., & Mirabella, G. (2020). Threatening facial expressions impact goal-directed actions only if task-relevant. *Brain Sciences*, 10(11), 1–18. https://doi.org/10.3390/brainsci10110794

March, D. S., Gaertner, L., & Olson, M. A. (2017). In harm's way: On preferential response to threatening stimuli. *Personality and Social Psychology Bulletin*, 43(11), 1519–1529. https://doi.org/10.1177/0146167217722558

March, D. S., Gaertner, L., & Olson, M. A. (2018). On the prioritized processing of threat in a dual implicit process model of evaluation. *Psychological Inquiry*, 29(1), 1–13. https://doi.org/10.1080/1047840X.2018.1435680

Mast, F., Frings, C. (2014). The impact of the irrelevant: The task environment modulates the impact of irrelevant features in response selection. *Journal of Experimental Psychology: Human Perception and Performance*, 40(6), 2198–2213. https://doi.org/10.1037/a0038182

Matchett, G., & Davey, G. C. (1991). A test of a disease-avoidance model of animal phobias. *Behaviour research and therapy*, *29*(1), 91-94.

Mather, M., & Sutherland, M. R. (2011). Arousal-biased competition in perception and memory. *Perspectives on Psychological Science*, 6(2), 114–133. https://doi.org/10.1177/1745691611400234

McNally, R. J. (2018). Attentional bias for threat: Crisis or opportunity? *Clinical Psychology Review*. https://doi.org/10.1016/J.CPR.2018.05.005

Mineka, S., & Öhman, A. (2002). Phobias and preparedness: the selective, automatic, and encapsulated nature of fear. *Biological Psychiatry*, 52(10), 927–937. https://doi.org/10.1016/S0006-3223(02)01669-4

Mogg, K., & Bradley, B. P. (2018). Anxiety and threat-related attention: cognitive-motivational framework and treatment. *Trends in Cognitive Sciences,* 22(3), 225–240. https://doi.org/10.1016/j.tics.2018.01.001

Moraglia, G. (1989). Display organization and the detection of horizontal line segments. *Perception Psychophysics*, 45(3), 265–272. https://doi.org/10.3758/BF03210706

Morris, J. S., Öhman, A., & Dolan, R. J. (1999). A subcortical pathway to the right amygdala mediating "unseen" fear. *Proceedings of the National Academy of Sciences*, *96*(4), 1680-1685.

Mulkens, S. A., de Jong, P. J., & Merckelbach, H. (1996). Disgust and spider phobia. *Journal of abnormal psychology*, *105*(3), 464.

Neisser, U. (1967) Cognitive psychology. Appleton-Century-Crofts.

Nesse, R. M. (2006). The smoke detector principle. *Annals of the New York Academy of Sciences*, 935(1), 75–85. https://doi.org/10.1111/j.1749-6632.2001.tb03472.x

Nothdurft, H. C. (1993a). Saliency effects across dimensions in visual search. *Vision Research*, 33(5–6), 839–844. https://doi.org/10.1016/0042-6989(93)90202-8

Nothdurft, H. C. (1993b). The role of features in preattentive vision: Comparison of orientation, motion and colour cues. *Vision Research*, 33(14), 1937–1958. https://doi.org/10.1016/0042-6989(93)90020-W

Nothdurft, H. C. (2002). Attention shifts to salient targets. *Vision Research*, 42(10), 1287–1306. https://doi.org/10.1016/S0042-6989(02)00016-0

O'Toole, L. J., DeCicco, J. M., Hong, M., & Dennis, T. A. (2011). The impact of task-irrelevant emotional stimuli on attention in three domains. *Emotion*, 11(6), 1322–1330. https://doi.org/10.1037/a0024369

Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology: General*, 130(3), 466–478. https://doi.org/10.1037/0096-3445.130.3.466

Öhman, A., & Mineka, S. (2001). Fears, phobias, and preparedness: toward an evolved module of fear and fear learning. *Psychological Review*, 108(3), 483–522. doi.org/10.1037//0033-295X.108.3.483

Öhman, A., & Mineka, S. (2003). The malicious serpent: Snakes as a prototypical stimulus for an evolved module of fear. *Current Directions in Psychological Science*, 12(1), 5–9. https://doi.org/10.1111/1467-8721.01211

Öhman, A., Soares, S. C., Juth, P., Lindström, B., & Esteves, F. (2012). Evolutionary derived modulations of attention to two common fear stimuli: Serpents and hostile humans. *Journal of Cognitive Psychology*, 24(1), 17–32. https://doi.org/10.1080/20445911.2011.629603

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, Vol. 372. https://doi.org/10.1136/bmj.n71

Parkhurst, D., Law, K., Niebur, E. (2002). Modeling the role of salience in the allocation of overt visual attention. *Vision Research*, 42(1), 107–123. https://doi.org/10.1016/S0042-6989(01)00250-4

Peirce, J. W. (2007). PsychoPy — Psychophysics software in Python. *Journal of Neuroscience Methods*, 162(1–2), 8–13. https://doi.org/10.1016/J.JNEUMETH.2006.11.017

Pessoa, L., & Ungerleider, L. G. (2005). Visual attention and emotional perception. In *Neurobiology of attention* (pp. 160-166). Academic Press.

Polák, J., Rádlová, S., Janovcová, M., Flegr, J., Landová, E., & Frynta, D. (2020). Scary and nasty beasts: Self-reported fear and disgust of common phobic animals. *British Journal of Psychology*, 111(2), 297–321. https://doi.org/10.1111/bjop.12409

Reinecke, A., Becker, E. S., & Rinck, M. (2009). Selective visual working memory in fear of spiders: the role of automaticity and material-specificity. *Journal of Anxiety Disorders*, 23(8), 1053–1063. https://doi.org/10.1016/j.janxdis.2009.07.007

Rigoulot, S., D'Hondt, F., Defoort-Dhellemmes, S., Despretz, P., Honoré, J., & Sequeira, H. (2011). Fearful faces impact in peripheral vision: Behavioural and neural evidence. *Neuropsychologia*, 49(7), 2013–2021. https://doi.org/10.1016/j.neuropsychologia.2011.03.031

Rigoulot, S., D'Hondt, F., Honoré, J., & Sequeira, H. (2012). Implicit emotional processing in peripheral vision: Behavioural and neural evidence. *Neuropsychologia*, 50(12), 2887–2896. https://doi.org/10.1016/j.neuropsychologia.2012.08.015

Sawaki, R., & Luck, S. J. (2010). Capture versus suppression of attention by salient singletons: Electrophysiological evidence for an automatic attend-to-me signal. *Attention, Perception, and Psychophysics*, 72(6), 1455–1470. https://doi.org/10.3758/APP.72.6.1455

Sawaki, R., & Luck, S. J. (2011). Active suppression of distractors that match the contents of visual working memory. *Visual Cognition*, 19(7), 956–972. https://doi.org/10.1080/13506285.2011.603709

Schmidt, L. J., Belopolsky, A. V., & Theeuwes, J. (2015). Attentional capture by signals of threat. *Cognition and Emotion*, 29(4), 687–694. https://doi.org/10.1080/02699931.2014.924484

Schreij, D., Los, S. A., Theeuwes, J., Enns, J. T., Olivers, C. N. L. (2014). The interaction between stimulus-driven and goal-driven orienting as revealed by eye movements. *Journal of Experimental Psychology: Human Perception and Performance*, 40(1), 378–390. https://doi.org/10.1037/a0034574

Schubö, A. (2009). Salience detection and attentional capture. *Psychological Research*, 73(2), 233–243. https://doi.org/10.1007/s00426-008-0215-x

Schupp, H. T., Stockburger, J., Codispoti, M., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2006). Stimulus novelty and emotion perception: The near absence of habituation in the visual cortex. *NeuroReport*, 17(4), 365–369. https://doi.org/10.1097/01.wnr.0000203355.88061.c6

Soares, S. C., Esteves, F., Lundqvist, D., & Öhman, A. (2009). Some animal specific fears are more specific than others: Evidence from attention and emotion measures. *Behaviour research and therapy*, *47*(12), 1032-1042.

Soares, S. C., Kessel, D., Hernández-Lorca, M., García-Rubio, M. J., Rodrigues, P., Gomes, N., & Carretié, L. (2017). Exogenous attention to fear: Differential behavioural and neural responses to snakes and spiders. *Neuropsychologia*, 99, 139–147. https://doi.org/10.1016/J.NEUROPSYCHOLOGIA.2017.03.007

Stilwell, B. T., Gaspelin, N. (2021). Attentional suppression of highly salient colour singletons. *Journal of Experimental Psychology: Human Perception and Performance*, 47(10), 1313–1328. https://doi.org/10.1037/xhp0000948

Subra, B., Muller, D., Fourgassie, L., Chauvin, A., & Alexopoulos, T. (2017). Of guns and snakes: Testing a modern threat superiority effect. *Cognition and Emotion*, 1–11. https://doi.org/10.1080/02699931.2017.1284044

Theeuwes, J. (1991). Exogenous and endogenous control of attention: The effect of visual onsets and offsets. *Perception Psychophysics*, 49(1), 83–90. https://doi.org/10.3758/BF03211619

Theeuwes, J. (1992). Perceptual selectivity for colour and form. *Perception Psychophysics*, 51(6), 599–606. https://doi.org/10.3758/BF03211656

Theeuwes, J., & Burger, R. (1998). Attentional control during visual search: The effect of irrelevant singletons. *Journal of Experimental Psychology: Human Perception and Performance*, 24(5), 1342–1353. https://doi.org/10.1037/0096-1523.24.5.1342

Theeuwes, J. (2010). Top-down and bottom-up control of visual selection. *Acta Psychologica*, 135(2), 77–99. https://doi.org/10.1016/j.actpsy.2010.02.006

Trujillo, N., Gómez, D., Trujillo, S., López, J. D., Ibáñez, A., & Parra, M. A. (2021). Attentional bias during emotional processing: Behavioural and electrophysiological evidence from an emotional flanker task. *PLoS ONE*, 16(4 April 2021), e0249407. https://doi.org/10.1371/journal.pone.0249407

Van Hooff, J. C., Devue, C., Vieweg, P. E., & Theeuwes, J. (2013). Disgust- and not fear-evoking images hold our attention. *Acta Psychologica*, 143(1), 1–6. https://doi.org/10.1016/j.actpsy.2013.02.001

Van Hooff, J. C., van Buuringen, M., El M’rabet, I., de Gier, M., & van Zalingen, L. (2014). Disgust-specific modulation of early attention processes. *Acta Psychologica*, 152, 149–157. https://doi.org/10.1016/j.actpsy.2014.08.009

Van Strien, J. W., Christiaans, G., Franken, I. H. A., & Huijding, J. (2016). Curvilinear shapes and the snake detection hypothesis: An ERP study. *Psychophysiology*, 53(2), 252–257. https://doi.org/10.1111/psyp.12564

Van Strien, J. W., & Isbell, L. A. (2017). Snake scales, partial exposure, and the Snake Detection Theory: A human event-related potentials study. *Scientific Reports*, 7(1), 1–9. https://doi.org/10.1038/srep46331

Van Zoest, W., Donk, M., & Theeuwes, J. (2004). The role of stimulus-driven and goal-driven control in saccadic visual selection. *Journal of Experimental Psychology: Human perception and performance*, *30*(4), 746.

Vermeulen, N., Godefroid, J., & Mermillod, M. (2009). Emotional modulation of attention: Fear increases but disgust reduces the attentional blink. *PLoS ONE*, 4(11), 2–6. https://doi.org/10.1371/journal.pone.0007924

Vernon, L. L., & Berenbaum, H. (2002). Disgust and fear in response to spiders. *Cognition and Emotion*, 16(6), 809–830. https://doi.org/10.1080/02699930143000464

Vogt, J., De Houwer, J., Crombez, G., & Van Damme, S. (2013). Competing for attentional priority: Temporary goals versus threats. *Emotion*, 13(3), 587–598. https://doi.org/10.1037/a0027204

Vromen, J., Lipp, O. V., & Remington, R. W. (2015). The spider does not always win the fight for attention: Disengagement from threat is modulated. *Cognition and Emotion*, 29(7), 1185–1196.

Vromen, J. M. G., Lipp, O. V., Remington, R. W., & Becker, S. I. (2016). Threat captures attention, but not automatically: Top-down goals modulate attentional orienting to threat distractors. *Attention, Perception, and Psychophysics*, 78(7), 2266–2279. https://doi.org/10.3758/s13414-016-1142-3

Vuilleumier, P., Armony, J. L., Driver, J., & Dolan, R. J. (2001). Effects of attention and emotion on face processing in the human brain: an event-related fMRI study. *Neuron*, *30*(3), 829-841.

Wang, B., & Theeuwes, J. (2020). Salience determines attentional orienting in visual selection. *Journal of Experimental Psychology: Human Perception and Performance*, *46*(10), 1051.

Wang, L., Yang, L. C., Meng, Q. L., & Ma, Y. Y. (2018). Superior colliculus-pulvinar-amygdala subcortical visual pathway and its biological significance. *Sheng li xue bao:[Acta physiologica Sinica]*, *70*(1), 79-84.

Waters, A. M., Lipp, O. V., & Spence, S. H. (2004). Attentional bias toward fear-related stimuli:: An investigation with nonselected children and adults and children with anxiety disorders. *Journal of experimental child psychology*, *89*(4), 320-337.

Williams, L. M., Palmer, D., Liddell, B. J., Song, L., & Gordon, E. (2006). The "when" and "where" of perceiving signals of threat versus non-threat. *NeuroImage*, 31(1), 458–467. https://doi.org/10.1016/j.neuroimage.2005.12.009

Wolfe, J. M., Yee, A., & Friedman-Hill, S. R. (1992). Curvature is a Basic Feature for Visual Search Tasks. *Perception*, 21(4), 465–480. https://doi.org/10.1068/p210465

Wolfe, J. M. (2000). Visual attention. In: De Valois KK, editor. Seeing. 2nd ed. San Diego, CA: Academic Press; 2000. p. 335-386. In D. V. K (Ed.), Seeing (2nd ed., pp. 335-386.). CA: Academic Press. http://discovery.ucl.ac.uk/6027/

Wolfe, J. M., & Horowitz, T. S. (2017). Five factors that guide attention in visual search. *Nature Human Behaviour*, *1*(3), 0058.

Wolfe, J. M. (2021). Guided Search 6.0: An updated model of visual search. *Psychonomic Bulletin & Review*, *28*(4), 1060-1092.

Woody, S. R., McLean, C., & Klassen, T. (2005). Disgust as a motivator of avoidance of spiders. *Journal of Anxiety Disorders*, 19(4), 461–475. https://doi.org/10.1016/j.janxdis.2004.04.002

Xu, M., Li, Z., Ding, C., Zhang, J., Fan, L., Diao, L., & Yang, D. (2015). The divergent effects of fear and disgust on inhibitory control: An ERP study. *PLoS ONE*, 10(6), 1–15. https://doi.org/10.1371/journal.pone.0128932

Xu, M., Li, Z., Fan, L., Sun, L., Ding, C., Li, L., & Yang, D. (2016). Dissociable effects of fear and disgust in proactive and reactive inhibition. *Motivation and Emotion*, 40(2), 334–342. https://doi.org/10.1007/s11031-015-9531-9

Yin, S., Liu, Y., Petro, N. M., Keil, A., & Ding, M. (2018). Amygdala adaptation and temporal dynamics of the salience network in conditioned fear: A single-trial fmri study. *ENeuro*, 5(1). https://doi.org/10.1523/ENEURO.0445-17.2018

Zinchenko, A., Al-Amin, M. M., Alam, M. M., Mahmud, W., Kabir, N., Reza, H. M., & Burne, T. H. J. (2017). Content specificity of attentional bias to threat in post-traumatic stress disorder. *Journal of Anxiety Disorders*, 50, 33–39. https://doi.org/10.1016/j.janxdis.2017.05.006

Zinchenko, A., Geyer, T., Müller, H. J., & Conci, M. (2020). Affective modulation of memory-based guidance in visual search: Dissociative role of positive and negative emotions. *Emotion*, 20(7), 1301–1305. https://doi.org/10.1037/emo0000602

Zsido, A. N., Bernath, L., Labadi, B., & Deak, A. (2018). Count on arousal: Introducing a new method for investigating the effects of emotional valence and arousal on visual search performance. *Psychological Research*. https://doi.org/10.1007/s00426-018-0974-y

Zsido, A. N., Deak, A., Losonci, A., Stecina, D., Arato, A., & Bernath, L. (2018). Investigating evolutionary constraints on the detection of threatening stimuli in preschool children. *Acta Psychologica*, 185. https://doi.org/10.1016/j.actpsy.2018.02.009

Zsido, A. N., Csatho, A., Matuz, A., Stecina, D., Arato, A., Inhof, O., & Darnai, G. (2019). Does threat have an advantage after all? – Proposing a novel experimental design to investigate the advantages of threat-relevant cues in visual processing. *Frontiers in Psychology*, 10(SEP). https://doi.org/10.3389/fpsyg.2019.02217

Zsido, A. N., Deak, A., & Bernath, L. (2019). Is a snake scarier than a gun? the ontogenetic-phylogenetic dispute from a new perspective: The role of arousal. *Emotion*, 19(4). https://doi.org/10.1037/emo0000478

Zsido, A. N., Matuz, A., Inhof, O., Darnai, G., Budai, T., Bandi, S., & Csatho, A. (2020). Disentangling the facilitating and hindering effects of threat-related stimuli – A visual search study. *British Journal of Psychology*, 111(4). https://doi.org/10.1111/bjop.12429

Zsidó, A. N., Stecina, D. T., Cseh, R., & Hout, M. C. (2022). The effects of task-irrelevant threatening stimuli on orienting-and executive attentional processes under cognitive load. *British Journal of Psychology*, *113*(2), 412-433.

Zsido, A. N., Stecina, D. T., & Hout, M. C. (2022). Task demands determine whether shape or arousal of a stimulus modulates competition for visual working memory resources. *Acta Psychologica*, 224, 103523. https://doi.org/10.1016/J.ACTPSY.2022.103523

Zsidó, A. N., Bali, C., Kocsor, F., & Hout, M. C. (2023). Task-irrelevant threatening information is harder to ignore than other valences. *Emotion*, *23*(6), 1606.

Zsido, A. N., Matuz, A., Julia, B., Darnai, G., & Csathó, Á. (2023). The interference of negative emotional stimuli on semantic vigilance performance in a dual-task setting. *Biologia Futura*, 1, 1–11. https://doi.org/10.1007/s42977-023-00180-5

List of Own Publications

Publications in the Topic of the Dissertation

Papers

Pakai-Stecina, D. T., & Zsidó, N. A. (2023). A vizuális tulajdonságok mentén kiugró ingerek hatása az inger-és célvezérelt figyelmi folyamatokra: szisztematikus áttekintés. *Magyar Pszichológiai Szemle*, 78(3), 375-407.

Pakai-Stecina, D. T., Hout, M. C., Bali, C., & Zsido, A. N. (2024). Can the processing of task-irrelevant threatening stimuli be inhibited? – The role of shape and valence in the saliency of threatening objects. *Acta Psychologica*, 243, 104150.

Pakai-Stecina, D. T., Kiss, B. L., Basler, J., Zsidó, A. N. (2024). Visual features drive attentional bias for threat. *Visual Cognition, 31:8, 599-616.*

Arató, Á., **Stecina**, D. T., Losonci, A., & Zsidó, A. N. (2017). Fenyegető ingerek észlelése mindennapi és negatív helyzetekben. *Impulzus – szegedi pszichológiai tanulmányok*, 4(1).

Zsido, A., Deak, A., Losonci, A., **Stecina**, D., Arato, A., & Bernath, L. (2018). Investigating evolutionary constraints on the detection of threatening stimuli in preschool children. *Acta Psychologica*, 185, 166–171. http://doi.org/10.1016/j.actpsy.2018.02.009

Zsido, A. N., Csatho, A., Matuz, A., **Stecina**, D., Arato, A., Inhof, O., & Darnai, G. (2019). Does threat have an advantage after all? – Proposing a novel experimental design to investigate the advantages of threat-relevant cues in visual processing. *Frontiers in Psychology*, 10. http://doi.org/10.3389/fpsyg.2019.02217

Zsidó, A. N., **Stecina**, D. T., & Hout, M. C. (2022). Task demands determine whether shape or arousal of a stimulus modulates competition for visual working memory resources. *Acta Psychologica*, 224.

http://doi.org/10.1016/j.actpsy.2022.103523

Zsidó, A. N., **Stecina**, D. T., Cseh, R., & Hout, M. C. (2022). The effects of task-irrelevant threatening stimuli on orienting- and executive attentional processes under cognitive load. *British Journal of Psychology*. http://doi.org/10.1111/bjop.12540

Conference Abstracts

Stecina, D. T., Losonci, A., Arató, Á., & Zsidó, A. N. (2017). *Jobb félni, mint megijedni – fenyegető ingerek észlelése mindennapi és negatív helyzetekben*. In Személyes Tér – Közös Világ (p. 319).

Stecina, D. T., Cseh, R., Basler, J., & Zsidó, A. N. (2020). *Can we ignore threats? The competition of bottom-up and top-down attentional mechanisms in a visual search task.* In IX. Interdiszciplináris Doktorandusz Konferencia 2020 Absztraktkötet (pp. 176–176).

Stecina, D. T., Cseh, R., Basler, J., & Zsidó, A. N. (2021). *Suppressing signals: the competition of goal-driven and stimuli-driven attentional control in the presence of threatening stimuli.* In Abstracts of the 63rd Conference of Experimental Psychologists (pp. 236–236).

Stecina, D. T., Cseh, R., Basler, J., & Zsidó, A. N. (2021). *Do we inhibit or do we attend to threatening stimuli? An eye-tracking study of signal suppression*. In Medical Conference for PhD Students and Experts of Clinical Sciences 2021 (pp. 88–88).

Stecina, D. T., Cseh, R., & Zsidó, A. N. (2021). *A figyelem jel-elnyomás hipotézisének tesztelése érzelmi ingerek esetén.* In Út a reziliens jövő felé. A Magyar Pszichológiai Társaság XXIX. Országos Tudományos Nagygyűlése (pp. 55–56).

Stecina, D. T., Bali, C., Zsidó, A. N. (2022). *Általános vonás detekció és a fenyegető ingerek gátlásának nehézségei / General Feature Detection and the Difficulties of Inhibiting Threatening Stimuli.* In XX. Szentágothai János

Mutidiszciplináris Konferencia és Hallgatói Verseny Absztrakt kötet (pp. 249-250).

Pakai-Stecina, D. T., Zsidó, A. N. (2023). *Investigating the saliency of threatening stimuli: General Features vs. Valence.* In TeaP 2023: Abstracts of the 65th Conference of Experimental Psychologists (p. 67).

Zsidó, A. N., Arató, Á., **Stecina**, D. T., Losonci, A., & Bernáth, L. (2017). *Guns on the streets and snakes in the grass – The role of the context in visual threat detection*. In TeaP 2017, Abstracts of the 59th Conference of Experimental Psychologists (pp. 43–44).

Zsidó, A. N., Cseh, R., & **Stecina**, D. T. (2021). *Fenyegető ingerek hatása a figyelmi orientációra és végrehajtó figyelemre.* In Út a reziliens jövő felé. A Magyar Pszichológiai Társaság XXIX. Országos Tudományos Nagygyűlése (pp. 54–55).

Zsidó, A. N., **Stecina**, D. T. & Hout, M. C. (2021). *The role of shape and arousal in competition for visual working memory resources.* In PSACON2021 Booklet (pp. 30–31).

Zsidó, A. N., **Stecina**, D. T., Cseh, R., & Hout, M. C. (2021). *The effects of task-irrelevant threatening stimuli on orienting- and executive attentional processes under cognitive load.* In Psychonomic Society 2021 Annual Meeting (p. 1).

Zsidó, A. N., Matuz, A., **Stecina**, D. T., Cseh, R., & Csatho, Á. (2021). *What is the arousal stimulation effect? – The facilitating effects of threat-related stimuli on visual search performance.* In Abstracts of the 63rd Conference of Experimental Psychologists (pp. 279–279).

Zsidó, A. N., Bali, C., **Stecina**, D. T., Lábadi, B. (2022). *Bottom-up and top-down effects of emotionally charged task-irrelevant stimuli under various load conditions.* In TeaP 2022 : Abstracts of the 64th Conference of Experimental Psychologists (p. 1).

Publications Outside of the Topic of the Dissertation

Papers and Book Chapters

Zsido, A. N., Arato, N., Lang, A., Labadi, B., **Stecina**, D., & Bandi, S. A. (2020). The connection and background mechanisms of social fears and problematic social networking site use: a Structural Equation Modeling analysis. *Psychiatry Research*, 292. http://doi.org/10.1016/j.psychres.2020.113323

Zsido, A. N., Arato, N., Lang, A., Labadi, B., **Stecina**, D., & Bandi, S. A. (2021). The role of maladaptive cognitive emotion regulation strategies and social anxiety in problematic smartphone and social media use. *Personality and Individual Differences*, 173. http://doi.org/10.1016/j.paid.2021.110647

Zsidó, A., Arató, N., Inhóf, O., Budai, T., **Stecina**, D., & Lábadi, B. (2021). A Bizonytalanságintolerancia Skála rövidített változatának magyar nyelvű adaptációja. *Mentálhigiéné és Pszichoszomatika*, 22(1), 103–120. http://doi.org/10.1556/0406.22.2021.003

Lábadi, B., Arató, N., Budai, T., Inhóf, O., **Stecina**, D. T., Sík, A., & Zsidó, A. N. (2022). Psychological well-being and coping strategies of elderly people during the COVID-19 pandemic in Hungary. *Aging & mental health*. http://doi.org/10.1080/13607863.2021.1902469

Zsidó, A. N., Arato, N., Inhof, O., Matuz-Budai, T., **Stecina**, D. T., & Labadi, B. (2022). Psychological well-being, risk factors, and coping strategies with social isolation and new challenges in times of adversity caused by the COVID-19 pandemic. *Acta Psychologica*. http://doi.org/10.1016/j.actpsy.2022.103538

Zsidó, A. N., Arató, N., Matuz-Budai, T., **Stecina**, D. T., Inhóf, O., Sík, A., Lábadi, B. (2022). *Idősek és egyetemisták pszichológiai jólléte és megküzdési stratégiái a COVID-19 járvány idején Magyarországon*. In: V., Komlósi Annamária; Polonyi, Tünde (szerk.) A világjárvány pszichológiája. Budapest, Magyarország : Oriold és Társai Kiadó, pp. 81-85.

Stecina, D. T., Arató, Á., Zsidó, A. N., Darnai, G., & Janszky, J. (2019). *A nikotinfüggőség nemi különbségeinek vizsgálata agyi képalkotó eljárással*. In Összetart a sokszínűség (p. 278).

Arató, Á., **Stecina**, D. T., Zsidó, A. N., Darnai, G., & Janszky, J. (2019). *A problémás internethasználat és a kognitív kontroll kapcsolata*. In Összetart a sokszínűség (pp. 231–232).

Arató, Á., **Stecina**, D. T., Zsidó, A. N., Darnai, G., & Janszky, J. (2019). *Mit okoz az internethasználat? A problémás internethasználat és az egzekutív gátlásban bekövetkező alterációk.* In Összetart a sokszínűség (pp. 239–240).

Ihász, V., Bali, C., Basler, J., Cseh, R., **Stecina**, D. T. & Zsidó, A. N. (2020). *Own-age effect on emotional face detection*. In BCCCD 2020 (Budapest CEU Conference on Cognitive Development) (p. 146).

Bali, C., **Stecina**, D. T., & Zsidó, A. N. (2020). *Óvodás gyermekek felidézési teljesítményének vizsgálata multimédiás eszközök használata során*. In IX. Interdiszciplináris Doktorandusz Konferencia 2020 Absztraktkötet (pp. 182–182).

Basler, J., **Stecina**, D. T., & Zsidó, A. N. (2021). A szociális szorongás kapcsolata a különböző érzelmeket kifejező arcok felismerésével. In Út a reziliens jövő felé. A Magyar Pszichológiai Társaság XXIX. Országos Tudományos Nagygyűlése (pp. 56–56).