Doctoral School of Psychology of the University of Pécs
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Spatial Perception and Inhibition of Emotional vs. Visual Cues of Threatening Stimuli

Theses of Doctoral (PhD) dissertation

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1. General Introduction

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.

2. Introduction on Visually Salient Stimuli – A Systematic Review

2.1 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.

2.2 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).

2.3 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).

2.4 Discussion

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).

3. Introduction on the Salience of Threatening Stimuli – A Narrative Review

3.1 Aim of this Review

For this narrative review, we selected studies that used threatening stimuli as task-irrelevant distractors. 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.)

3.2 Discussion

Our 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.

4. Can the Processing of Task-Irrelevant Threatening Stimuli Be Inhibited?

4.1 Aims and hypotheses

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. 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 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

In Experiment 1, a total of 49 students (mean age = 19.9, SD = 1.52) participated. In Experiment 2, a total of 23 students participated (mean age = 20.1, SD = 1.43). 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. Data was collected in Hungary, at designated laboratories in the building of the Institute of Psychology, University of Pécs.

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; 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.

4.2.3 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. 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 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. Each session of data collection lasted between 30 and 45 minutes.

In Experiment 2, the same stimuli were presented as in Experiment 1. Eye-movements were recorded. 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.

4.3 Results

Our first hypothesis was not entirely confirmed by Experiment 1. 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. The results of Experiment 2 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

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.

5. The Role of Disgust in the Inhibition of Task-Irrelevant Stimuli

5.1 Aims and hypotheses

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.

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

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. Data was collected in Germany, at designated laboratories in the building of the Institute of Psychology, University of Hildesheim.

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.

5.3 Results

Consistent with our hypotheses, inhibiting disgusting distractors posed greater challenges compared to neutral ones. This pattern was particularly evident in the close distance condition. Compared with Study II, our findings also revealed 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.

5.4 Discussion

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

6.1 Aims and hypotheses

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 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.

6.2.1 Participants

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.

6.2.2 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.

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.

6.2.3 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.

6.2.4 Results and 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 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 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.

6.3.2 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.

6.3.3 Results and 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 Discussion

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 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).

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,

Study nr.	Experiment nr.	Paradigm	Main result
			but it appears that disgust cannot be extracted from our threatening stimuli.
Study IV.	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.
	Replication of Experiment 1		

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. References

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List of Own Publications

Publications in the Topic of the Dissertation

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