Navigating the Maze of Attention: Exploring Interactions Among Stimulus, Individual Characteristics, and Context in Threat Perception

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Article

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Abstract

An ongoing debate exists in the literature regarding the reliability of attention bias to threats. The current study directly examined how the interaction between available attention resources, personality traits, and stimuli visual characteristics moderates attention bias to task-irrelevant threatening stimuli. To this end, the current study conducted a comprehensive series of four experiments in which an emotional modification of the perceptual load task was employed. Participants with high and low fear of spiders, as well as participants diagnosed with arachnophobia, performed the task under high and low perceptual loads while ignoring task-irrelevant distracting spiders. As expected, all participants, regardless of fear level, were affected to some extent by the threatening distracting spider pictures, known to evoke threat due to their evolutionary value. However, the results show that high fear and phobia groups exhibit consistent attention bias to threats, depending on the threat's ecological value. The low fear groups, on the other hand, showed a similar but weaker attention bias to threat, only when attentional resources were available.These results deomstratethe variance in individuals' capacity to inhibit distracting threats and focus on current goals.

Introduction

Cognitive biases, particularly evident in various psychopathologies such as anxiety disorders, are characterized by selective processing mechanisms where negative stimuli are prioritized over others[1,2]. One of these biases is **attention bias**, manifesting as quicker engagement with threatening stimuli, delayed disengagement from it, and subsequently threat avoidance[3]. Extensively studied, attention bias is believed to significantly contribute to the onset and persistence of fear and anxiety[4]. However, despite this widely accepted notion, some studies have failed to replicate these claims regarding the involvement of attention bias in anxiety disorders, reporting null results or even reversed effects instead[5–7]. This inconsistency may arise from the complex interplay between stimulus-related factors and individual characteristics across different studies[8].

Previous research has studied the effects of various factors on attention bias separately, but rarely in unison. For instance, studies found that orienting of attention to emotionally irrelevant distractors varies depending on **individual traits**[9]. Individuals with high, but not low, levels of anxiety often exhibit interference by task-irrelevant threatening stimuli in different attentional tasks[10]. Similarly, research suggests that individuals with specific phobias exhibit reduced response efficiency when confronted with fear-related stimuli, compared to non-phobic individuals[11,12].

A second factor that influences distractors' processing is **the availability of attention resources**. For example, in an emotional modification of the perceptual load task, individuals with higher levels of animal fears showed a bigger interference in detecting targets when presented with phobia-related distractors compared to when presented with neutral distractors. However, this attention bias was found only when there were enough attention resources to detect the distractor, but not when attentional resources were exploited by the demanding task[12]. Thus, the processing of negative distractors is dependent on both sufficient attention resources as well as on individual traits[13].

Lastly, the processing of distracting stimuli is also influenced by their **visual and perceptual characteristics**. Processing advantage occurs when the stimulus stands out from its surroundings[14,15], or contains features that are more naturalistic and have a larger ecological validity compared to controlled, simplified stimuli[16,17]. For instance, a recent study found stronger attention bias toward spiders when they were presented on an ecological and natural background, compared to when presented on a white, sterile background[18]. Thus, while a white background might provide sharper contrast and stronger pop-out effects, an ecological background might elicit stronger feelings of realism and consequent attention bias (see also Zsidó et al.,[19] 2019, for more on the effect of context and background on threat detection).

Recently, studies have simultaneously examined some of the factors mentioned above and their combined effects on attention toward task-irrelevant threats. Namely, Zsidó et al.[20] (2023) manipulated task relevance, valence, and cognitive load in a visual search task. The results showed that participants responded more slowly when threatening distractors were presented, and fixated on them earlier and longer, compared to other valences (non-threatening negative pictures, positive and neutral pictures), especially under higher cognitive load. In a later study[21], task relevance, valence, and visual characteristics of stimuli were manipulated, also in a visual search task. To assess the influence of the stimuli's valence compared to its visual features, half of the threatening and neutral distractors had similar shapes (e.g., snakes vs. worms) and half didn't (e.g., guns vs. worms). The Results of this study suggest that the threatening value of the stimuli drives attentional biases more than its visual features. Collectively, these findings indicate prioritized processing and interference effects induced by threatening distractors, alongside interactions between valence and cognitive load.

The Current Study

As noted above, several factors can influence attention bias toward threatening stimuli. However, research concerning the interaction between these factors is scarce. Therefore, the current study manipulated three factors: an individual's level of fear of spiders, availability of attention resources, and stimulus characteristics, to examine how the interaction between these factors affects attention bias toward threatening task-irrelevant pictures.

In a comprehensive and systematic series of four experiments, individuals' level of fear of spiders was assessed by comparing individuals with high and low levels of fear of spiders, and by comparing individuals with diagnosed spider phobia to individuals without spider fear. The threat level of the stimulus was manipulated by presenting pictures with a negative valence (spiders or angry faces, as these have been extensively used in previous experiments as threatening targets in visual search tasks[18,22–24] vs. neutral pictures. The availability of attentional resources was manipulated by two levels of perceptual load (low or high load) amongst the distracting stimulus appeared. Finally, stimulus characteristics were manipulated by using different picture sets that differ in their pop-out and ecological features. Reviewed collectively, these studies systematically examine the cumulative impact of different factors on attention bias, potentially providing valuable insights for future clinical and therapeutic contexts, as well as guiding cognitive interventions.

Experiment 1: Interaction between valence, individual fear level, attentional resources, and distractors' ecological value.

In Experiment 1, we examined how attention bias is influenced by the interaction of *valence* (spider vs. bird distractors), individual fear level (high vs. low fear of spiders), *attention resources* (high vs. low perceptual load), and *stimulus characteristics* (grayscale vs. colored pictures). The experiment contained two blocks: one block consisted of colored pictures of spiders and birds on human hands. The other block consisted of grayscale pictures of spiders and birds on a natural background. We hypothesized an interaction between perceptual load and the valence of distractors, wherein interference effects would be more pronounced for spider distractors than for bird distractors, but only under conditions of low perceptual load[25]. Additionally, we anticipated a greater interference from colored ecological distracting pictures compared to grayscale ones[18].

Results

Statistical analyses were performed with SPSS[26] and R Statistical Softwar[27]. Only RTs of correct target trials were analyzed. RTs that were 3 z-scores above or below each participant's average RT in a specific condition were corrected to the next high or low RT (less than 1% from all the trials).

Mean RTs were subjected to a 4-way repeated measures analysis of variance (ANOVA), with the following factors: picture valence, load, and stimuli's type as within-subject factors and participants group as a between-subjects factor. The main effect of the load was significant [$F_{(1,60)}$ = 2701.39, p < .001, η^2=.978], due to faster RTs in the low load condition compared to the high load condition [Mean RTs low load: 481.25 ms; Mean RTs high load: 731.49 ms]. The main effects of picture type, valence, and group were not significant (all ps > .26). A significant interaction emerged between load and valence [$F_{(1,60)}$ = 6.89, p = .011, η^2=.103]. Further investigation of the interaction showed a simple effect of valence in the low load condition [$t_{(61)}$ = 3.002, p = .004], indicating faster RTs for the neutral stimuli compared to the negative stimuli. In contrast, no difference in RTs was found in the high load condition.

Although the interaction between load, valence, stimuli type and group was not significant, we examined the interaction between valence and load separately for each group and stimuli type, to test our a-priori hypothesis of a difference as a function of group and stimuli type.

In the colored block, in both fear groups a main effect of load was found [Low fear Group: $F_{(1,32)}$ = 1455.37, $p < .001$, η^2=.978; High fear group: $F_{(1,28)}$ = 910.25, $p < .001$, η^2=.97]. In both groups, the main effects of valence were again not significant (all ps > .2). However, in the high fear group, the interaction between valence and load was significant [$F_{(1,28)}$ = 7.57, p = .010, η^2=.212]. This interaction stemmed from significant differences in RTs in the low load condition [$t_{(28)}$ = 2.071, p = .048], indicating slower RTs for the negative stimuli compared to the neutral stimuli. This effect was not found in the low fearful group nor the grayscale block. Results are presented in Fig. 1.

Discussion

Consistent with our hypothesis, the presence of threatening distractors affected only the low perceptual load condition, as manifested by slower RTs when distracting spider pictures were presented compared to neutral bird pictures. Hence, threatening pictures interfered with performance even though they were task-irrelevant and participants were encouraged to ignore them. In contrast, when the perceptual load was high, the distracting stimuli did not influence performance in any of the task conditions. When examining each fear group and stimuli characteristics separately, the threatening stimuli interfered with task performance in the low load only for participants who had a high fear of spiders and when colored spider pictures (i.e., ecological pictures) were presented.

These findings replicate prior research, demonstrating that the manipulation of attentional resources through perceptual load influences the processing of irrelevant distractors[12,13,25]. Although the pattern was identical for both colored and grayscale pictures, the follow-up analyses showed a significant effect only for the colored block. This finding strengthens the notion that colored pictures induced a strong negative emotion in participants due to their ecological value[28] and saliency[8]. Another factor that could have affected valence is that in the colored block, both spiders and birds appeared on human hands, which might have increased their threat value compared to the grayscale block that presented the animals in a natural background. Moreover, it remains unclear whether the lack of influence of grayscale pictures on attentional processing is due to their reduced visual saliency compared to their backgrounds (which include various other grayscale visual features) or their reduced ecological validity (being achromatic). To address this ambiguity and specifically control for saliency and complexity, Experiment 2 presented simple grayscale pictures devoid of backgrounds. These images were anticipated to be more visually salient and easily detectable compared to the grayscale pictures with backgrounds used in Experiment 1.

Experiment 2: Colored vs. grayscales salient distractors in spider fear

In Experiment 2, attentional orientation to distracting spiders was further examined. Here, the visual characteristics of the stimuli were manipulated, such that one block contained the same colored animal pictures as Experiment 1. In the second block, each animal picture was presented without context, on a white background, increasing saliency and reducing ecological validity. This manipulation allows examination of the effect of ecological validity on attention bias to threat (in line with previous studies[18,19]. An additional aim of Experiment 2 was to replicate the findings of the colored block, to improve reliability.

Results

Four-way ANOVA indicated a main effect of load [$F(_{1,63})$ = 3,116.17, $p < .001$, η^2=.98], due to faster RTs in low compared to high load trials. There were no main effects of stimuli type, group, or valence (*ps* > .08). An interaction was found between load and valence [$F_{(1,63)}$ = 6.49, p = .013, η^2=.85], due to faster RTs for neutral stimuli compared to negative stimuli only in the low load condition [$t_{(64)}$ = 5.516, $p < .001$].

Similarly to Experiment 1, although the interaction between load, valence, group, and stimuli type was not significant, we examined the interaction between load and valence as a function of group and stimuli type. The effect of load was found for both groups in both blocks (*ps* < .001). In the colored block, although no interactions were found, analysis of the simple effects was done according to our a-prior hypothesis. A significant difference emerged only in the low load condition for both the high fear group [$t_{(32)}$ = 3.83, $p < .001$] and the low fear group [$t_{(31)}$ = 3.62, p = .001]. In the non-background block, an interaction emerged for valence and load [$F_{(1,63)}$ = 4.52, p = .037, η^2=.07]. Further analysis found a significant effect in the low load only, both for the high fearful group [$t_{(32)}$ = 2.07, p = .047] and the low fearful group [$t_{(31)}$ = 2.55, p = .016] (see Fig. 2). Hence, both fear groups showed slower RTs for negative compared to neutral distractors only in the low load condition, both in the colored block and the grayscale salient distractors block.

Discussion

Experiment 2 replicated the findings of Experiment 1, showing interference of spider distractors only in low-load conditions when attention resources were available. Two differences emerged between Experiments 1 and 2. First, interference effects emerged in participants with both high and low levels of fear of spiders. Second, interference emerged for colored as well as no-background pictures. Both differences may be due to a 'pop-out' effect in the no-background pictures in Experiment 2, which is known to induce effortless and quick stimulus detection [15]. Beck and Kastner[29] (2005) discovered that, in contrast to heterogeneous displays, pop-out stimuli are processed in the early visual cortex irrespective of top-down attentional control. This suggests that a stimulus's saliency level leads to neural and behavioral prioritization over competing stimuli. This phenomenon may elucidate the attention bias towards threatening stimuli observed in the absence of a background condition.

In addition, attention bias was found in the low fear group for the colored pictures block, unlike Experiment 1. This result suggests that attention bias is found among the general population, regardless of fear levels (for more on cognitive biases in health and in psychiatric disorders, see Aue & Okon-

Singer[30], 2020). Nevertheless, the findings of the two experiments demonstrate a small effect that may be less reliable for individuals with low fear levels. To examine this explanation, Experiment 3 focused on a population with a high fear of spiders, reaching a clinical threshold.

Experiment 3: Colored vs. grayscale salient distractors in spider phobia

Experiment 3 was identical to Experiment 2, only here participants were diagnosed with spider phobia. Thus, while in Experiment 2 participants had subclinical levels of spider fear (low vs. high fear levels), here participants had clinical levels of spider phobia (diagnosed participants vs. participants with no phobia exhibiting low fear levels). This experiment aimed to examine whether the findings of Experiment 2 replicate in a clinical sample. In addition, based on previous studies[12], we expected the phobic group to demonstrate attention bias in the high load conditions as well.

Results

Groups significantly differed in their post-task state anxiety levels ($t_{(49)}$ = 5.93, p < .001). Phobic participants showed higher levels of state anxiety (*M* = 55.54, *SD = 11.4*) compared to the healthy control group (*M* = 36.2, *SD = 11.42*).

A 4-way ANOVA of load, valence, group, and picture type showed again a significant main effect of load [$F_{(1,48)}$ = 1117.3, p < .001, η^2=.96]. There were no main effects of stimuli type, group, or valence (*ps* > .4). An interaction was found between load and valence [$F_{(1,48)}$ = 16.22, p < .001, η^2=.26], due to faster RTs for neutral stimuli compared to negative stimuli in the low load condition [$t_{(47)}$ = 2.76, p = .008], and slower RTs for neutral stimuli compared to negative stimuli in the high load condition [$t_{(47)}$=-3.07, p = .004].

Although the interaction between load, valence, group, and stimuli type was not significant, we examined the interaction between load and valence as a function of group and picture type. A load effect was found for both groups in both blocks (*ps* < .001). In the colored block, although no interactions were found, analysis of the simple effects was conducted according to our a-prior hypothesis and based on the results of the previous experiments. A significant difference between the picture's valence emerged in the low load condition for the no phobia group [$t_{(24)}$ = 2.27, p = .032], as RTs were slower when the distracting picture was a spider compared to a neutral picture.

In the no background block, an interaction emerged between valence and load for both groups (No phobia group: $F_{(1,24)}$ = 4.75, p = .039, η^2=.17; Phobic participants: $F_{(1,24)}$ = 11.7, p = .002, η^2=.33). Further analysis showed a significant simple effect of picture valence for the phobic group in the high load condition [$t_{(24)}$ = 2.5, p = .013], indicating faster reactions to the phobic-related pictures compared to neutral pictures, and a marginally significant effect in the low load condition [$t_{(24)}$ = 2.03, p = .054], indicating faster reactions to neutral pictures compared to the phobic-related pictures]. Hence, both groups showed some interference from the negative spider pictures, however, this interference was dependent on load and stimuli characteristics. For results, see Fig. 3.

Discussion

The aim of Experiment 3 was to extend results from Experiment 2 to participants who were diagnosed with spider phobia. Using the same paradigm as Experiment 2, participants in Experiment 3 showed similar results. Specifically, in the low load, both groups of participants exhibited effects of interference by spider distractors, replicating results from Experiment 2 with the two fear groups. In this experiment, it was found once again that the results are context-dependent, as participants in the low fear group were more affected by colorful pictures while participants with spider phobia were more affected by grayscale, no-background pictures.

Yet, some of the results of Experiment 3 were surprising. Contrary to healthy participants with high or low fear levels, in the high load participants diagnosed with spider phobia detected the threatening pictures content and exhibited facilitation by distracting spider pictures, rather than hindered performance. These results suggest that participants with diagnosed phobia actively look for threats in their environment, even when their cognitive resources are low. This is in contrast to low fear participants, whose performance is hindered by task-irrelevant distractors only when attentional resources are available, thus making their search process more goal-oriented.

While Experiments 1 to 3 provided an integrative view of how task-related factors and individual characteristics interact and affect attention to threatening distractors, these effects were limited to spider distractors. The combined effects and interaction of the aforementioned factors toward other threatening stimuli remain unknown.

Experiment 4: Colored vs. face distractors

Experiment 4 aimed at extending the examination of the effect of visual characteristics on attention to threat by presenting pictures of angry faces instead of spiders. Specifically, angry faces have often been used as threatening targets in visual search paradigms and attention bias has been found toward emotional face targets[31,32]. We expected to find attention bias toward angry faces that is similar to attention bias toward spiders.

Results

One participant from the high fear group, who was 3 z-scores above the participants' average was excluded from the analysis. A 4-way ANOVA of load, valence, group, and picture type showed again a significant main effect of load [$F_{(1,64)}$ = 4573.48, p < .001, η^2=.986]. For further investigation of the influence of stimuli characteristics on performance, although the 3-way interactions were not significant, the interaction between valence and load was conducted separately for each block and group, similarly to the previous experiments. A load effect was found for both groups in both blocks (all *ps* < .001). In the colored block, a significant effect was found in the low load condition only for the high fearful group [$t_{(31)}$ = 2.416, p = .019], indicating faster RTs for the neutral stimuli compared to the spider stimuli (see Fig. 4). For the faces block, simple effects were not found in both loads, for both groups (all ps. >0.18).

Discussion

Replicating the findings of Experiments 1, 2, and 3, Experiment 4 showed that under low load, spider pictures interfered with the performance of participants with high fear, resulting in slower RTs compared to bird distractors (for a results summary of all experiments, see Table 1). In contrast, angry face pictures did not capture attention more than the bird stimuli.

The absence of attention bias toward angry faces observed in our study aligns with prior research demonstrating that an attentional bias toward socially threatening stimuli is evident primarily in anxious individuals rather than non-anxious participants[33–35]. For instance, Mogg, Philippot, and Bradley[36] (2004) discovered a distinction in attention bias toward angry faces between individuals with clinical social phobia and healthy controls. Specifically, when exposed to threatening facial stimuli for a brief period (e.g., 500 ms), only participants in the clinical social phobia group displayed initial orienting toward threat cues. In the same line, research indicates that among non-socially anxious participants, attention bias toward angry faces varies with presentation duration[37]. In brief presentations (e.g., 100 ms), non-anxious participants show an attentional bias toward the location of the threatening facial expression, whereas this pattern reverses in longer presentations (e.g., 500 ms). Additionally, findings suggest an interaction between cognitive load and emotional face valence, whereby threatening facial distractors only induce task interference for non-anxious participants under conditions of low cognitive load (O'Toole et al., 2011).

Nevertheless, Given that an angry facial expression is a salient signal of threat and was presented for a short duration of time in the current experiment (i.e. 200ms) and there are other studies suggesting that angry faces do indeed capture attention even among healthy participants[38], it is somewhat surprising that in this experiment we did not find an attentional bias to the threatening facial expressions. It is possible that the fact that we used bird pictures as neutral stimuli, unlike previous studies that used neutral facial expressions, influenced performance. This is in line with previous studies[39] that suggest that different contexts influence the processing of emotional facial expressions. An example of this phenomenon is the categorization of a neutral face picture as more pleasant when it follows the presentation of a happy face sequence than after sad sequences[40], or the observation that attention bias toward angry faces is evident only when there is a priming activation of a social processing mode[41]. Thus, it is possible that the angry faces in this experiment were perceived as less negative as participants were unable to compare them to more positive or neutral facial expressions.

General Discussion

The current research examined how the interaction between availability of attention resources, stimulus visual characteristics, and levels of spider fear, affect the reliability of attentional bias to task-irrelevant threatening stimuli. In a series of four experiments, we manipulated attention resources (low/high perceptual load), valence (threatening/neutral), stimulus characteristics (high/low ecological value, high/low saliency, animal/face identity), and individual levels of fear of spiders (high/low). To the best of our knowledge, this is the first systematic investigation conducted with the same paradigm examining different aspects affecting attention bias to task-irrelevant threatening distractors. Table 1 summarizes the findings. Taken together, the results show that high fear and phobia groups exhibit consistent attention bias to threat, depending on available attentional resources and the threat's ecological value. The low fear groups, on the other hand, showed a similar but weaker attention bias to threat. The results indicate that distracting spider stimuli that were salient, visually simple, and easy to detect (i.e., grayscale pictures of spiders without background) interfered with the performance of all participants. When these distracting stimuli were less salient and more complex (i.e., grayscale pictures of spiders with a complex background), participants with both high and low levels of fear of spiders managed to ignore them.

Across all experiments, we observe prioritized processing of threatening stimuli when adequate attentional resources are present. This phenomenon is consistent across varying levels of spider fear, ranging from low fear to high fear, and among spider-phobic participants, suggesting that the drawing of attention primarily arises from the threatening nature of the stimuli rather than individual fear levels. However, this effect appears to be modest, consistently present in individuals with higher fear levels but not always observed in those with lower fear levels, indicating on an interplay with individual traits that amplify attention toward threatening stimuli. Thus, the inclination toward paying attention to threatening stimuli when sufficient attention resources are available does not adhere to binary classification, segregating individuals into those significantly fearful and those only mildly so. Instead, it appears to manifest along a spectrum, initially influenced by the attributes of the stimulus itself and subsequently modulated by the individual's relevance to the threatening stimuli. These results are also in line with the notion that attentional allocation is not only related to stimulus threat levels but also correlates with stimulus relevance to the self. For example, previous studies found that attention was quickly drawn to the stimulus of most personal relevance in the environment, whether the stimulus contained positive or negative valence[42].

Interestingly, these results change when attentional resources are limited, and the task at hand is particularly demanding. Under these circumstances, we observed a facilitation effect, indicating faster reaction times when the threatening stimuli were present, solely within the spider-phobic group. This suggests that individuals with phobia experience an enhancement in processing fear-related stimuli regardless of the cognitive demands of the task, which is not observed in non-phobic individuals. Notably, attention bias to the fear-related stimuli fastened the detection of the target letter in the task, suggesting participants experienced heightened arousal leading to higher engagement with the demanding task. These findings are consistent with recent models positing that maladaptive responses in anxiety and stress-related disorders manifest differently depending on the level of contextual danger[43]. For example, individuals with anxiety display heightened threat vigilance in safe contexts, while demonstrating a tendency towards threat avoidance in objectively dangerous situations. Consequently, this model underscores the maladaptive nature of anxiety disorders, emphasizing that attention to threat in a hazardous environment is indeed adaptive and likely to lead to adaptive outcomes. In contrast, when individuals remain attentive to minor threats even in safe environments, this can also evoke and prolong anxiety and stress[43].

The current results provide an integrative and systematic examination of task-related factors and individual characteristics that affect attentional orientation by task-irrelevant stimuli. This approach is in line with recent literature on the advantages of more holistic research, which takes into consideration various factors when measuring attention bias to threat, especially given the replicability crisis in psychology and the reliability crisis in the measurement of attention bias[44]. For instance, previous studies suggest that endogenous factors such as a-priori expectancy[45] and as well as prior attentional history[46] contribute to attentional allocation to threat, in addition to exogenous (task-related) factors such as contract and physical salience. The current findings have further clinical implications. A better understanding of the factors that influence the maladaptive allocation of attention in anxiety, and how phonic individuals react to threat compared to healthy individuals is crucial for developing effective therapeutic methods. One such intervention protocol, *attention bias modification* (ABM) aims to alleviate anxiety symptoms by reducing attention bias toward threats[47]. However, despite its initial premise, ABM has shown limited effectiveness in reducing anxiety[4]. Hence, enhancing our comprehension of the factors influencing attentional bias towards threats and their interactions holds promise for optimizing ABM and similar therapeutic approaches. For example, our findings underscore the importance of stimuli characteristics in shaping attentional bias manifestation, which can assist researchers in more effectively selecting ABM training stimuli. Additionally, our results highlight the significance of considering the interplay between the targeted population (e.g. phobic vs. high fearful individuals) and contextual cues (e.g. safety vs threat context) when designing such training protocols.

This study has several limitations. First, this study focused on how spiders induce fear reactions among the general population, and people with fear of spiders especially. It is well-documented that disgust plays a significant role in spider fear[48]. Hence, it is possible that the ability to ignore spider distractors also depends on individual disgust levels, a variable that was not controlled in the current experiment. Secondly, the current study aimed at providing an integrative investigation of the various factors that can affect attention toward and interference by threat. One factor that can also play a role in attention bias to threat is arousal, as previous studies found that it can also play a role in attention toward task-irrelevant threat[49,50]. Thus, while the current study manipulated stimuli’s valence (e.g., birds vs. spiders), future studies can also examine the role of arousal levels by experimentally manipulating participants’ arousal levels.

In summary, the current series of studies found attention bias to distracting spiders, but not angry faces, as a function of attention resources, individual fear level and threat saliency. A rather reliable attention bias to spiders was found for individuals with high spider fear levels when attention resources were available and the threatening stimulus was salient. Considering the important role attention bias is believed to have in the appearance and maintenance of anxiety, understanding the factors that modulate it is of high importance. These results can better explain the variance in people's capacity to inhibit distracting threats and focus on current goals. Such understanding may, in turn, optimize future treatments for anxiety disorders and specific phobias.

Materials and Methods

For all experiments, we report how we determined our sample size, all data exclusions (if any), all manipulations, and all measures in the study. Only the design and analysis plan for Experiment 4 were preregistered on the Open Science Framework's website (OSF; https://osf.io/v69hb). However, data for all experiments are available on the OSF website (https://osf.io/hr97u).

Experiment 1

Participants: Five hundred participants filled out the Fear of Spiders Questionnaire (FSQ; Szymanski & O'Donohue, 1995) via the online platform Prolific (https://www.prolific.co/) in April 2020. The questionnaire was delivered using the Qualtrics platform for running questionnaires online (https://www.qualtrics.com/), shown to present high-quality data collection (Peer et al., 2022; Sahar & Yeshurun, 2022). The FSQ is an 18-item self-report questionnaire assessing spider phobia. This questionnaire includes 18 statements measuring perceptions and beliefs about spiders, rated on a seven-point Likert scale, ranging from 1 to 7.

Sample size was determined using G*Power (version 3.1.9.7; Faul et al., 2009). A total of fifty-two participants (26 in each fear group) were needed to reach a medium effect size (η^2_p = .06; Cohen, 2013) and power of .95 with an error probability of .05 and 8 repeated measures (2 stimulus types × 2 valences × 2 cognitive load conditions), using the "as in SPSS" setting. 60-70 participants were recruited in each experiment, taking into account exclusion of participants due to post-experimental exclusion (see below).

In Experiment 1, seventy participants were recruited based on their scores in the FSQ. Participants were divided into two groups by using the cut-off score of 68 in the FSQ, as was done in our previous study (Abado et al., 2020). Thirty-five participants were recruited for the high fear group (i.e., above 68 in the FSQ), and thirty-five participants were recruited for the low fear group (i.e., below 40 in the FSQ).

The study was approved by the ethics committee of the School of Psychological Sciences at the University of Haifa (approval number: 467/19), and the experiment was performed in accordance with the guidelines and regulations of the university. Prior to the beginning of the experiment, informed consent was obtained from all participants. Inclusion criteria were age above 18 and good or corrected vision. Participants were excluded from the study if they reported a history of neurological disorders, ADHD diagnosis, or psychiatric diagnosis based on responses to Yes/No questions.

Participants with low accuracy rates (accuracy rates below 70%), a high rate of false alarms (more than 30% wrong answers in trials where no target appeared), or reaction times (RTs) above or below 3 Z-scores compared to participants' average RTs in the task were not included in the analysis. Two participants from the *low fearful* group and six participants from the *high fearful* group were excluded from the analysis due to a low accuracy rate; hence, the low fearful group consisted of 33 participants and the high fearful group consisted of 29 participants. FSQ scores significantly differed between the two groups [$t_{(61)}$=7.32, p<.001]. For detailed participants' characteristics, see Table 2.

The images utilized in this study were sourced from various image repositories, including the International Affective Picture System (Lang, Bradley, & Cuthbert, 2008), the Geneva Affective Picture Database (Dan-Glauser & Scherer, 2011), as well as from freely available pictures from the web. All pictures were resized to 254 × 338 pixels and were edited to a circle shape using patin.net 4.2.10 software. Both picture types were matched for luminance and contrast. The proportions of the object size, and distance between each other and from the screen center were fixed.

Emotional Modification of the Perceptual Load Task.

Participants performed an emotional modification of the perceptual load paradigm (Lavie, 1995; Okon-Singer, Tzelgov, & Henik, 2007). The task was created using E-Prime 3.0 software (Psychology Software Tools, Pittsburgh, PA, USA) and run by E-prime go 1.0.2 software. The experimental task comprised conditions of low and high perceptual load, which were defined by the presence of distracting letters on the screen. The low load condition involved the absence of any distracting letters accompanying the target letter, while the high load condition entailed the simultaneous appearance of five distracting letters alongside the target letter (see ***Figure 6***). Based on Lavie's study (1995), the target letter was either X or N and the distracting letters were K, H, V, Z, or W. The target and distracting letters appeared randomly in six possible locations that created an imaginary circle at the center of the screen. In the low load condition, as only one letter appears on the screen, the letter could be either a target letter or a distracting letter.

At the beginning of each trial, a fixation cross appeared for 500 milliseconds (ms) followed by the letters' presentation, which appeared on the screen until response or for 1,050 ms. Participants were instructed to quickly and accurately indicate the appearance of the target letter by pressing the corresponding key (X for the target letter X, N for the target letter N). Trials with no target letter were included to ensure participant's alertness and constituted 10% of the total trials. Simultaneously with the letter's onset, a picture of a spider or a bird (50% each) was presented in the middle of the screen for 200ms. Participants were instructed to ignore the picture (which was not relevant to the task) and to focus on the letters.

The experiment contained two blocks, each including a different set of pictures: a colored block and a grey-scale block. In both blocks, load conditions were presented randomly. The blocks were presented in a random order, with a break between them, in which participants were advised to stand and freshen up before continuing. Each block also contained two short breaks. Both blocks started with a practice phase, containing 36 trials that were identical to the task itself except that feedback was given on the participant's performance. Overall, the task included 792 trials (396 in each block, not including practice), and took between 25-30 minutes to complete.

Experiment 2

Participants: The recruitment of participants was identical to Experiment 1, and was performed in accordance with the guidelines and regulations of the university. Thirty-five participants were recruited to each fear group. None of the participants took part in Experiment 1. Three participants from the *low fear* group and two participants from the *high fear* group were excluded from the analysis due to low accuracy rates; hence, the low fear group consisted of 32 participants and the high fear group consisted of 33 participants. FSQ scores differed between the two groups [$t_{(64)}$=8.124, p<.001]. For detailed participants characteristics, see Table 2.

Stimuli: The number of stimuli and presentation method were identical to Experiment 1. This experiment contained again two picture sets: (i) ***Colored block***, identical to the stimuli used in experiment 1; (ii) ***No-background block***, containing a clean white background (for picture examples, see ***Figure 7***). As in Experiment 1, the chosen pictures of birds and spiders were matched for luminance and contrast.

Experiment 3

Participants: 670 participants filled out the Fear of Spiders Questionnaire (FSQ, Szymanski & O'Donohue, 1995), as well as demographic questions such as age and gender by using advertisements posted on social media. The questionnaires were presented using the Qualtrics platform for running questionnaires online (https://www.qualtrics.com/). Before participation, informed consent was obtained and participants were informed that the questionnaires would serve as a screening tool for later participation in the following experiments conducted in our lab.

Out of these participants, we recruited participants based on their FSQ scores. Participants who scored above 80 in the FSQ were invited to participate in a pre-experiment clinical interview by trained clinicians in exchange for 30 NIS. Out of 65 participants interviewed, 31 participants satisfied the criteria for a current diagnosis of spider-specific phobia on the ADIS-5L (Brown & Barlow, 2014). Out of them, 3 participants did not fully complete the experiment and 3 participants had low accuracy rates (accuracy rates below 70%), thus the group consisted of 25 participants. For the low fear group, we recruited participants with FSQ scores below 35. These participants were briefly interviewed to make sure that they did not exhibit a fear of spiders. For this group, we recruited 30 participants. One participant did not fully complete the experiment and 4 other participants had low accuracy rates; hence the group consisted of 25 participants. For detailed participants' characteristics, see Table 1.

The Anxiety and Related Disorders Interview Schedule for ADIS-5-L (Brown & Barlow, 2014), is a semi-structured interview designed to obtain a reliable diagnosis of the DSM-5 of anxiety, mood, specific phobias, and related disorders, as well as to screen for the presence of other conditions (e.g., eating disorders, agoraphobia, psychotic disorders). Furthermore, due to high rates of comorbidity of specific phobia with other anxiety disorders, and to ensure that the groups differ only in the diagnosis of spider phobia, we also examined generalized anxiety disorder (GAD) levels by using a clinician-administered version of the Generalized Anxiety Disorder Questionnaire-IV (GAD-Q-IV; Newman et al., 2002). The GAD-Q-IV is a nine-item questionnaire designed as an initial screen for the presence of GAD. Newman et al. (2002) report high two-week stability of GAD diagnoses based on the GAD-Q-IV (92%) and show excellent inter-rater agreement with the semi-structured diagnostic interview (Cohen’s k = .67). In the current experiment, GAD-Q-IV scores did not differ between the spider phobic group and the healthy group [$t_{(48)}$=1.68, *p*=.098], but differed in state anxiety after performing the task [$t_{(48)}$=5.89, *p*=<.001] suggesting the task was more stressful for spider phobia participants.

Stimuli, task, and questionnaires: The stimuli and task were identical to those of Experiment 2. At the end of the task, participants filled out the State-Trait Anxiety Inventory - State (STAI-S; Dan-Glauser & Scherer, 2011) to measure state stress levels after performing the task.

Experiment 4

Participants: The recruitment of participants was identical to Experiments 1 and 2, and informed consent was obtained before study participation. Thirty-five participants were recruited for each fear group, and none of the participants took part in the other experiments. Two participants from the *low fear* group and two participants from the *high fear* group were excluded from the analysis due to low accuracy. Hence, the low fear group consisted of 33 participants, and the high fear group consisted of 33 participants. FSQ scores differed between the two groups [$t_{(65)}$=8.062, *p*<.001]. The groups significantly differed in their anxiety scores, as participants in the high fear of spiders showed higher levels of state anxiety [$t_{(65)}$=3.08, *p*=.003]. For detailed participants' characteristics, see Table 1.

Stimuli, task, and questionnaires: The number of pictures, presentation way, and the stimuli of the colored spider pictures block remained identical to Experiments 1, 2, and 3. At the end of the task, participants filled out the State-Trait Anxiety Inventory - State (STAI-S; Dan-Glauser & Scherer, 2011) to measure state stress levels after performing the task.

The second block contained 30 colored pictures of angry faces (15 female pictures and 15 male pictures) and 30 colored pictures of birds (for example of the presented pictures, see ***Figure 8***). All angry face pictures were taken from the NimStim stimuli set (Tottenham et al., 2009). Birds and faces pictures were matched for luminance and contrast.

Declarations

Competing interests

The authors declare no competing interests.

Author Contribution

G.M.: Conceptualization, Methodology, Software, Formal analysis, Writing, Reviewing. E.G.: Conceptualization, Methodology, Software, Formal analysis, Writing, Figures Preparation, Reviewing. E.A.: Formal analysis, Writing, Reviewing. H.O-S.: Conceptualization, Methodology, Writing, Reviewing.

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Data Availability

For all experiments, we report how we determined our sample size, all data exclusions (if any), all manipulations, and all measures in the study. Only the design and analysis plan for Experiment 4 were preregistered on the Open Science Framework's website (OSF; https://osf.io/v69hb). However, data for all experiments are available on the OSF website (https://osf.io/hr97u).

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Tables

Table 1
Summary of all experiments results.

Experiment	**Study population**	**Block**	**Main effects**	**Interactions**	**Results in the low load**	**Results in the High load**
Experiment 1	Low or high fear of spiders	Colored block	Load (*p* < .001, η^2 = .97)	valence × load, only in the *high fear group* (*p* = .010, η^2 = .212)	Slower RTs for the negative, *only in the high fear group* (*p* = .048)	X
		Grayscale block with complex background	Load (*p* < .001, η^2 = .97)	X	X	X
Experiment 2	Low or high fear of spiders	Colored block	Load (*p* < .001, η^2 = .96)	X	Slower RTs for the negative, both for *the high fearful group* (*p* < .001) and the *low fearful group* (*p* = .001).	X
		No-background grayscale block	Load (*p* < .001, η^2 = .96)	valence × load, in both groups (*p* = .037, η^2 = .07).	Slower RTs for the negative stimuli, both for *the high fearful group* (*p* = .047) and *the low fearful group* (*p* = .016).	X
Experiment 3	Participants with low or spider phobic participants	Colored block	Load (*p* < .001, η^2 = .98)	X	Slower RTs for the negative stimuli, *for the low fearful group* (*p* = .032).	X
		No-background	Load	Valence × load for both	Slower RTs for the	Faster reactions to

Experiment	Study population	Block	Main effects	Interactions	Results in the low load	Results in the High load
		grayscale block	(*p* < .001, *η2* = .95)	low fearful (*p* = .039, *η2* = .17) and phobic participants (*p* = .002, *η2* = .326)	phobic-related stimuli, for *the phobic group* (*p* = .054)	the phobic-related stimuli compared to neutral ones, *for the phobic group* (*p* = .013)
Experiment 4	Low or high fear of spiders	Colored block	Load (*p* < .001, *η2* = .98)	X	Slower RTs for the negative stimuli, *for the high fearful group* (p = .019).	X
		Angry faces block	Load (*p* < .001, *η2* = .97)	X	X	X

Table 2
Participants' characteristics in all four experiments.

Experiment	**Group**	**N**	**Gender**	**Age** **Mean (SD)**	**Fear of spiders (FSQ)** **Mean (SD)**	**Generalized Anxiety (GAD-Q-IV)**	**State Anxiety (STAI-S)**
Experiment 1	Low spider fear High spider fear	33 29	10 females 18 females	26.64 (*11.2*) 28.77 (*10.5*)	24.27 (*5.9*) 89.41 *(12.7)*	- -	- -
Experiment 2	Low spider fear High spider fear	31 33	11 females 12 females	27.56 *(9.4)* 24.94 *(6.6)*	28.22 *(7.2)* 95.18 *(16.7)*	- -	- -
Experiment 3	Low spider fear Spider phobia	25 25	22 females 23 females	24.83 *(3.7)* 24.61 *(4.2)*	23.10 *(5.3)* 107.36 *(10.2)*	4.27 *(3.9)* 6.20 *(4.1)*	36.2 *(11.4)* 55.36 *(11.2)*
Experiment 4	Low spider fear High spider fear	33 33	11 females 17 females	26.46 *(7.3)* 27.72 *(8.1)*	23.45 *(6.2)* 97.15 *(15.1)*	- -	39.3 *(10.8)* 46.6 *(14.1)*

Stimuli: The study included 120 pictures and was comprised of two separate blocks, each containing a different stimulus set: *(A)* **Colored block**, containing 60 colored pictures of spiders or birds on a human hand (30 pictures of each animal type); *(B)* **Grayscale natural background block**, contained 60 achromatic pictures of spiders and birds (30 pictures of each animal type) in naturalistic backgrounds. The blocks were presented in a random order. For examples, see Fig. 5.

Figures

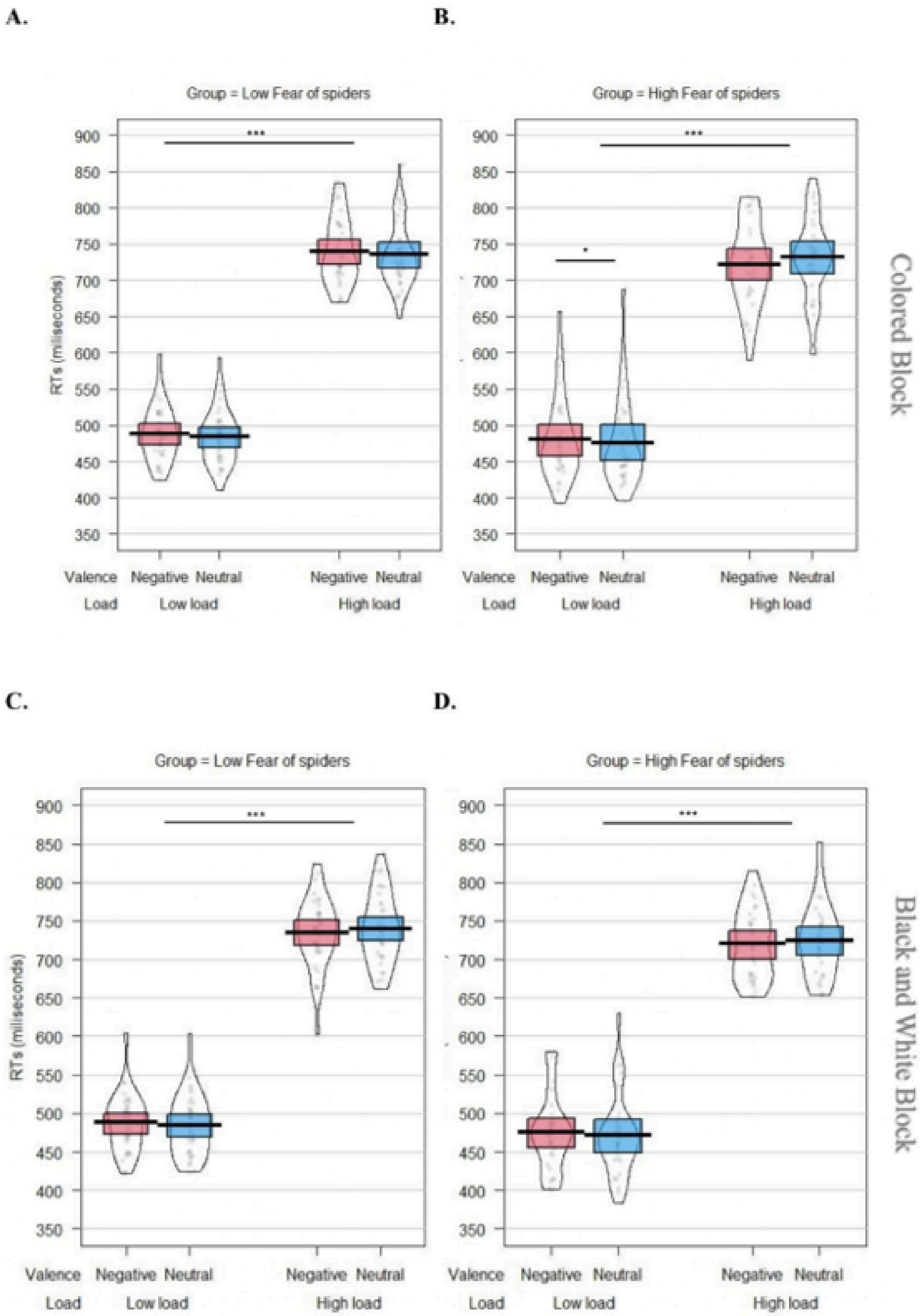

Figure 1

Mean RTs in the colored block and grayscale block in Experiment 1, as a function of load and picture valence; **(A.)** Mean RTs for the low fear of spider group in the colored block; **(B.)** Mean RTs for the high fear of spider group in the colored block; **(C.)** Mean RTs for the low fear of spider group in the grayscale block; **(D.)** Mean RTs for the high fear of spider group in the grayscale block. **p ≤ .05 **p ≤ .01 ***p ≤ .001*

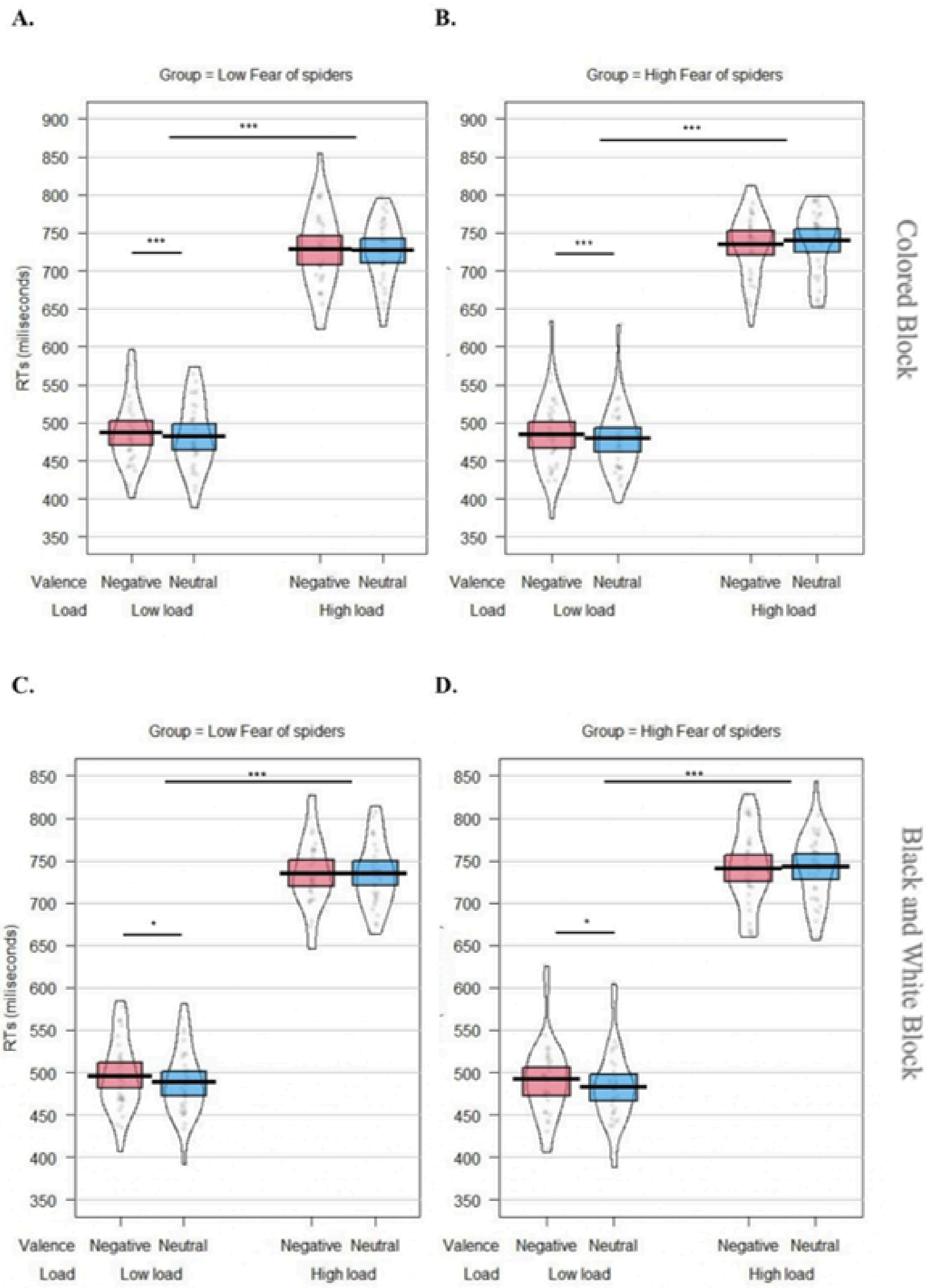

Figure 2

Mean RTs in the colored block and grayscale salient distractors block in Experiment 2, as a function of group, load, and picture valence; **(A)**Mean RTs for the low fear of spider group in the colored block; **(B)** Mean RTs for the high fear of spider group in the colored block; **(C)** Mean RTs for the low fear of spider group in the grayscale salient distractors block; **(D)**Mean RTs for the high fear of spider group in the grayscale salient distractors block. *$p \leq .05$ **$p \leq .01$ ***$p \leq .001$

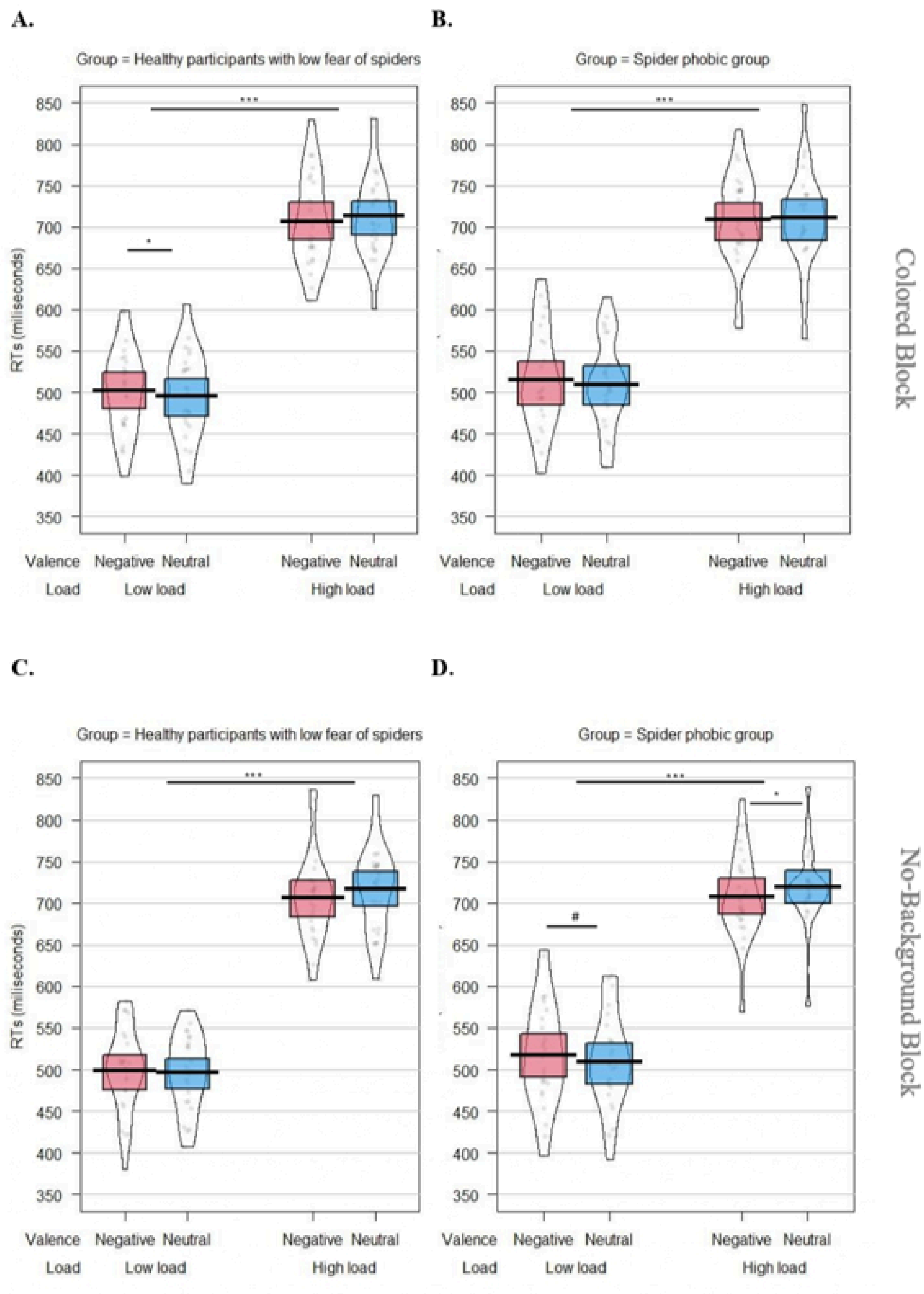

Figure 3

Mean RTs in the colored block and grayscale block in Experiment 3, as a function of load and picture valence; **(A.)** Mean RTs for the healthy low fear of spider group in the colored block; **(B.)** Mean RTs for the spider phobic group in the colored block; **(C.)** Mean RTs for the healthy low fear of spider group in the grayscale block; **(D.)** Mean RTs for the spider phobic group in the grayscale block. *# $p \leq .06$, *$p \leq .05$, ***$p \leq .001$*

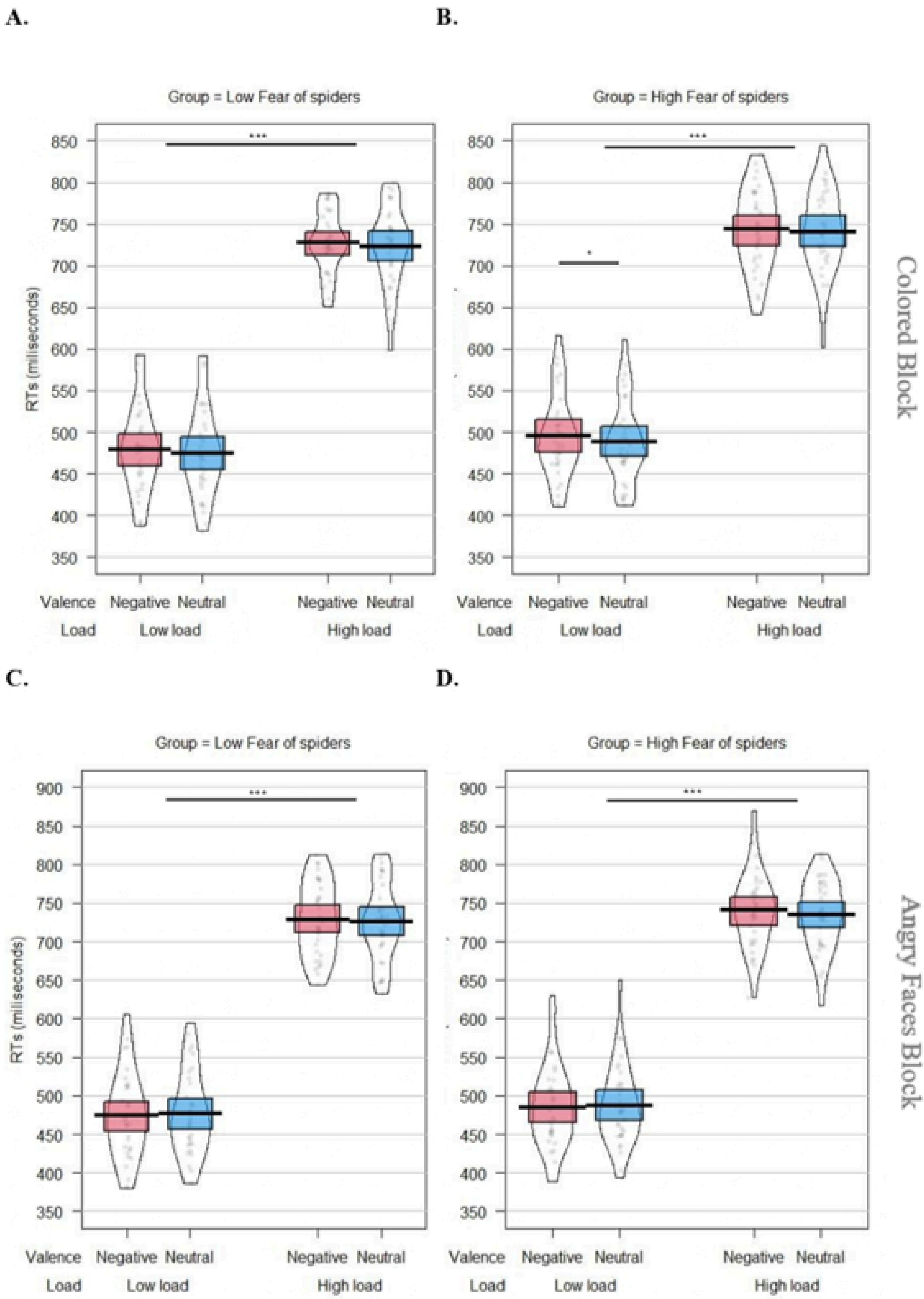

Figure 4

Mean RTs in the colored block and face block in Experiment 4, as a function of load and picture valence; **(A.)** Mean RTs for the low fear of spider group in the colored block; **(B.)** Mean RTs for the high fear of spider group in the colored block. **(C.)** Mean RTs for the low fear of spider group in the Angry Faces block; **(B.)** Mean RTs for the high fear of spider group in the Angry Faces block. *$*p \leq .05$ $**p \leq .01$ $***p \leq .001$*

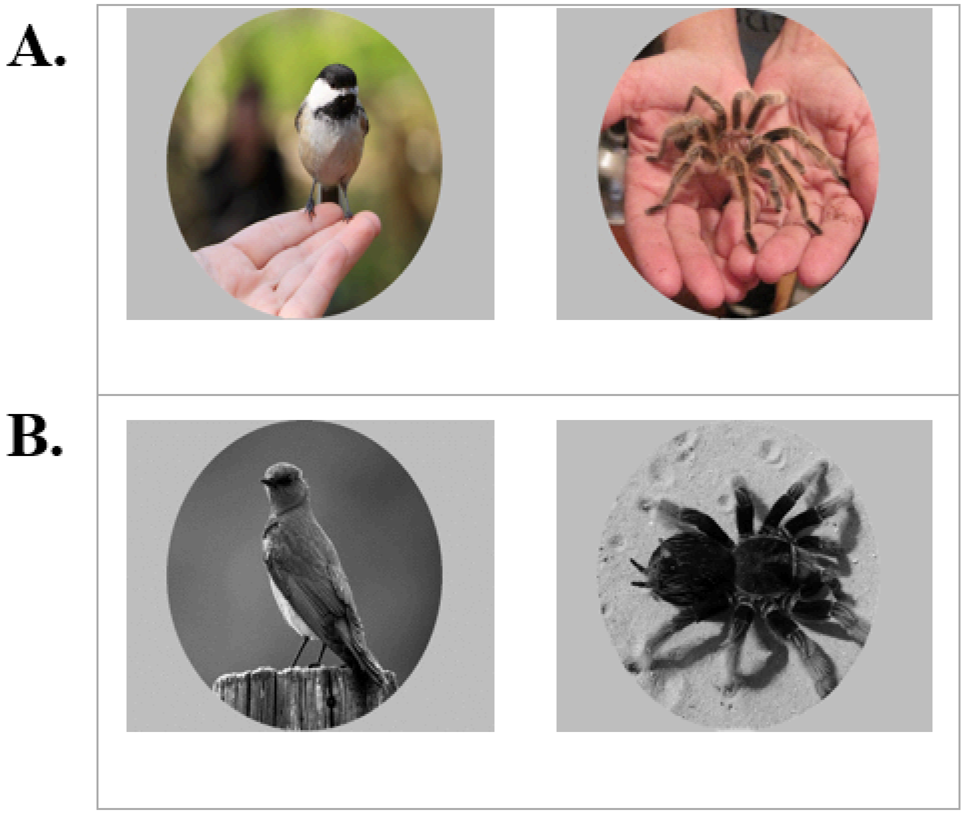

Figure 5

Examples of the stimuli used in experiment 1. **(A)** Two pictures taken from the colored block; A picture with a neutral valence (bird), and a picture with a negative valence (spider). Note that to enhance saliency and personal threat, all animals in the colored block were presented as standing on human hands. **(B)** Two pictures from the grayscale block; a picture with a neutral valence (bird), and a picture with a negative valence (spider).

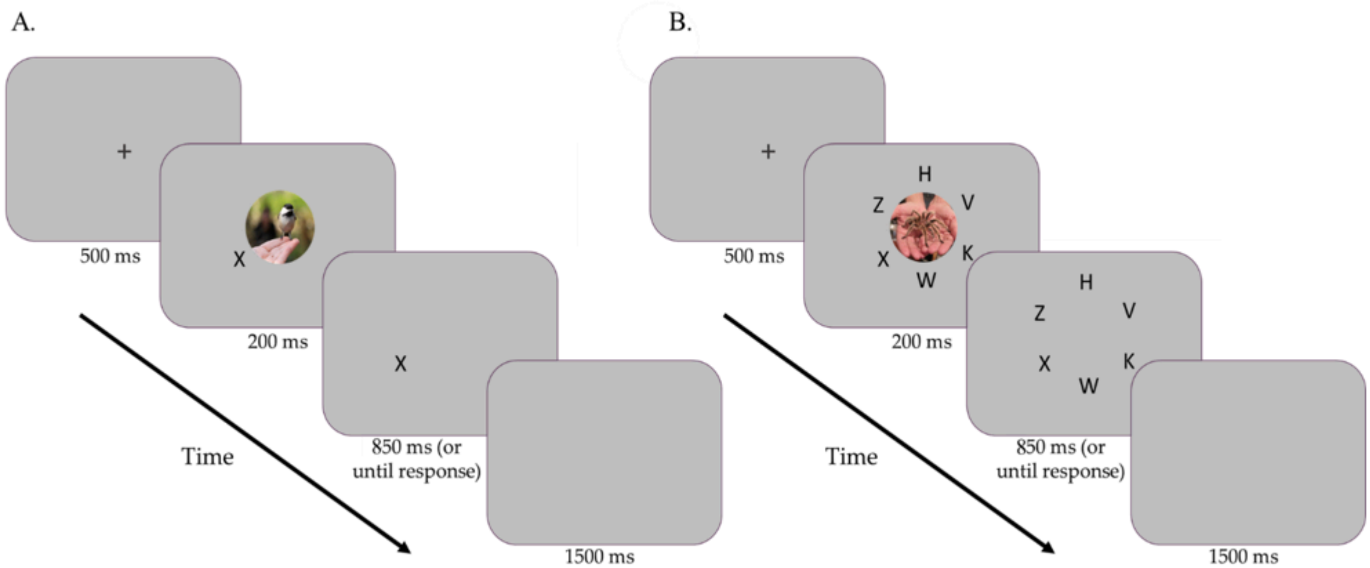

Figure 6

Examples of typical trials from the colored block**. (A)** Low load condition with a neutral picture trial; one target letter with a bird picture at the center. **(B)** High load condition with a negative picture trial; six letters with one target letter and a spider picture at the center.

Figure 7

Example stimuli from Experiment 2; **(A)** A picture with a neutral valence (bird), and a picture with a negative valence (spider) from the colored block. **(B)** A picture with neutral valence (bird), and a picture with negative valence (spider) from the grayscale block.

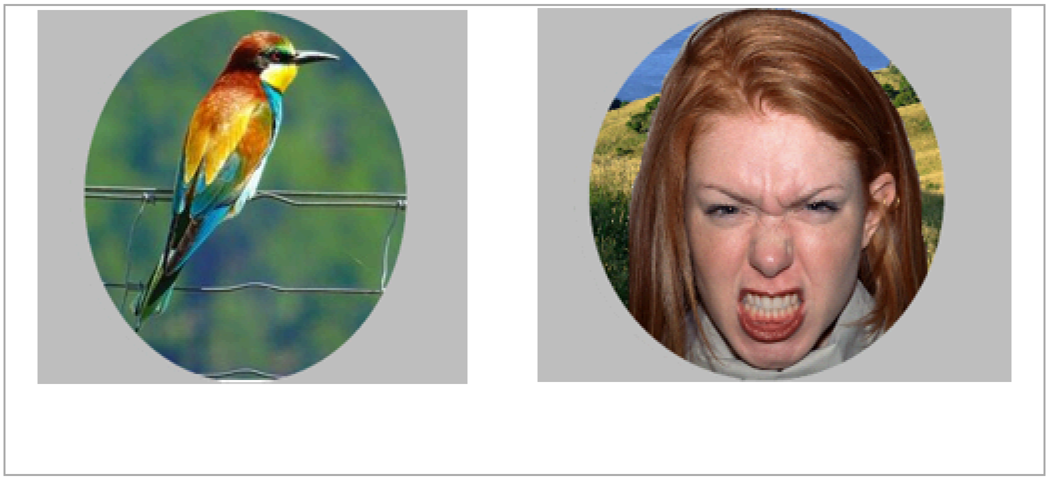

Figure 8

Examples from Experiment 3 of pictures from the face block. Left to right, a picture with neutral valence (bird), and a picture with negative (angry face).