

# Potential Threat Attracts Attention and Interferes With Voluntary Saccades

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Several studies have shown that threatening stimuli are prioritized by the visual system. In the present study we investigated whether a stimulus associated with a threat of electrical shock attracts attention and accordingly interferes with the execution of voluntary eye movements to other locations. In 2 experiments, we showed that when a fear-conditioned and a neutral stimulus were presented simultaneously, voluntary saccades were initiated faster toward fear-conditioned compared with neutral stimuli. Moreover, saccades often erroneously went to the location of threat even when a saccade to a different location was required. This implies an automatic shift of attention to a fear-conditioned stimulus that interferes with saccade execution. The same pattern of results was found for a neutral stimulus that was always presented together with the fear-conditioned stimulus and consequently itself became associated with threat. The current results indicate that threatening stimuli attract visual attention and subsequently bias saccade target selection in a reflexive fashion.

*Keywords:* attention, eye movements, emotion, fear conditioning, threat

In situations where multiple objects in the environment compete for attentional selection, the visual system must select which objects in the environment are given processing priority. The allocation of visual attention is thought to be influenced by both the relative salience of stimuli in the visual field, and by the goals and intentions of the observer (Egeth & Yantis, 1997; Yantis, 1996). According to bottom-up models of attention, early selection is primarily stimulus-driven, and physically salient stimuli induce an exogenous, reflexive shift of attention (Theeuwes, 1991, 1992, 2010).

Besides stimuli that are salient because of their physical appearance, stimuli with a high behavioral value are also thought to attract attention (LeDoux, 1996). Several behavioral studies have demonstrated that threatening stimuli are prioritized by the visual system (see for a review Vuilleumier, 2005). For example, it has been found that threatening pictures are quickly detected when presented in an array of neutral pictures (e.g., Ohman, Flykt, & Esteves, 2001; Rinck, Becker, Kellermann, & Roth, 2003; Soares, Esteves, Lundqvist, & Ohman, 2009), and search for a neutral target is interrupted when an emotional distractor is present (e.g., Lipp & Waters, 2007; Miltner, Krieschel, Hecht, Trippe, & Weiss, 2004; Rinck, Reinecke, Ellwart, Heuer, & Becker, 2005). Furthermore, using a spatial cueing task, it has been shown that when a threatening picture is briefly shown at one location, response times to targets at a different location were slower relative to when neutral pictures were shown (e.g., Fox, Russo, Bowles, & Dutton,

2001). However, several inconsistent results have also been reported (e.g., Becker, Anderson, Mortensen, Neufeld, & Neel, 2011; Lipp, Derakshan, Waters, & Logies, 2004) leaving open the question of whether threat attracts attention (see de Gelder, van Honk, & Tamiotto, 2011; Pessoa & Adolphs, 2010).

Inconsistencies in previous studies may be related to the nature of the threatening stimuli. Specifically, most studies investigating the effects of emotional content on attention used pictorial stimuli. These stimuli do by themselves not pose a genuine risk for the occurrence of an aversive event. Therefore, other studies have used fear-conditioning to create a more direct threat-inducing stimulus. Fear-conditioning is broadly used to study the effect of emotions on learning and memory (e.g., Effting & Kindt, 2007; Pischek-Simpson, Boschen, Neumann, & Waters, 2009). In this context, fear is defined as an anticipatory response to an event that predicts an aversive outcome. The term conditioning refers to learning of an association between two stimuli that are initially unrelated (Pavlov, 1927). In a classic fear-conditioning design, an initially neutral stimulus (conditioned stimulus [CS]) is associated with an aversive unconditioned stimulus (US), such as an electrical shock, and becomes intrinsically aversive (CS+), while another neutral stimulus remains unpaired (CS-).

Previous research examined how fear-conditioned stimuli affect attention. For example, using a dot—probe paradigm, it has been shown that after association with an aversive event, such as a loud noise or an electrical shock, an initially neutral cue caused facilitated engagement (Koster, Crombez, Van Damme, Verschuere, & De Houwer, 2004), facilitated attention shifting (Stormark & Hugdahl, 1996; Stormark, Hugdahl, & Posner, 1999), and delayed disengagement of attention (Van Damme, Crombez, & Notebaert, 2008). In addition, Notebaert, Crombez, Van Damme, De Houwer, and Theeuwes (2011) showed that a fear-conditioned stimulus facilitated response times to targets presented at the same location as that stimulus. Recently, we demonstrated that when participants are instructed to search for a neutral target, the presence of a fear-conditioned stimulus interferes with target detection. Re-

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sponse times to targets in presence of a fear-conditioned distractor were slower relative to a neutral distractor with similar physical salience (Schmidt, Belopolsky, & Theeuwes, 2014).

Overall, previous studies using threat-inducing stimuli suggest that threat attracts attention and cannot easily be ignored. A question that remains under debate is how potential threat engages the oculomotor system. Because covert spatial attention is closely related to saccadic eye movements, eye tracking has been widely used to study visual attention. The premotor theory of attention (Rizzolatti, Riggio, Dascola, & Umiltà, 1987) states that the mechanisms responsible for covert attention and the mechanisms involved in programming saccadic eye movements are basically the same (for exceptions see Belopolsky & Theeuwes, 2012). A covert shift of visual attention is often almost immediately followed by an overt gaze shift to the attended spatial location. The well-known oculomotor capture paradigm has shown that when participants are instructed to make a saccade to one location, the eyes are often captured automatically by a salient object even though this object is always irrelevant to the task (e.g., Theeuwes, Kramer, Hahn, & Irwin, 1998; Theeuwes, Kramer, Hahn, Irwin, & Zelinsky, 1999). Thus, eye movements serve as an overt behavioral measure of attentional allocation.

A few studies investigated the effect of emotional stimuli on eye movements. For example, it has been demonstrated that participants make faster saccadic eye movements toward a peripherally presented fearful picture than to a neutral one (e.g., Bannerman, Milders, de Gelder, & Sahraie, 2009; Bannerman, Milders, & Sahraie, 2010). Furthermore, when a fearful and a neutral stimulus were presented simultaneously, saccadic reaction times (RTs) toward fearful pictures in the right visual field were slowed (Kissler & Keil, 2008). However, in these experiments the fearful stimulus was always the task goal, and participants could have adopted a strategy of actively attending to it. In line with this idea, Hunt, Cooper, Hungr, and Kingstone (2007, exp 1), showed that when an angry face had to be detected in an array of neutral faces, eye movements were not directed faster to the angry faces compared with when a happy face needed to be detected, and eye movements were not captured more frequently by angry faces. Furthermore, Nummenmaa and colleagues (2009, exp1) conducted a study in which an emotional picture was presented together with a neutral picture, and observers had to make a saccade to a picture indicated by an imperative signal. They found faster saccades when the signal pointed toward the emotional picture rather than toward the neutral picture.

In a previous study, we simultaneously presented threatening and neutral distractors that were never the target of a saccade and were, therefore, always irrelevant to the task goal (Schmidt, Belopolsky, & Theeuwes, 2012). In that study participants had to make an endogenous saccade up or down while a face with an angry, neutral, or happy expression was present in the periphery. We showed that the presence of an angry face as distractor altered the eye movement trajectory and made the eyes curve away from its location, indicating that a threatening distractor had a direct influence on saccade programming. Mulckhuysse, Crombez, and Van der Stigchel (2013) replicated these findings with fear-conditioned distractors. Together these results show that even when emotional stimuli are not a part of the task goal and participants do not have an incentive to attend to them, stimuli with a negative emotional value can bias overt saccadic behavior.

Taken together, several studies have demonstrated an influence of threatening stimuli on the allocation of covert and overt attention. However, there exist still a lot of controversy about whether it is genuine threat that affects initial orienting and delays disengagement of attention. One reason for mixed results is that most previous studies have used pictorial representations of threat, which do not pose a genuine risk for the occurrence of an aversive event. Another reason for mixed results may be the difficulty in measuring initial attentional orienting based on manual responses.

In the present study, we aimed at investigating whether a potentially threatening stimulus interferes with the execution of a voluntary saccadic eye movement. Specifically, we examined whether potential threat attracts attention and consequently interferes with execution of saccades toward an endogenously cued target location. Two stimuli were presented briefly and simultaneously left and right of fixation. An arrow pointed to one of the locations, instructing participants to make a saccade as fast as possible in that direction. If potential threat automatically attracts attention, then making a saccade to that location would be relatively fast as attention is already allocated there. Conversely, if the threatening stimulus attracts attention and a saccade has to be made to the opposite location saccade should be relatively slow as to make a saccade, attention has to be shifted from the location of threat to the other location. In other words, we expect saccades to be initiated faster when the cue pointed toward the location of the threatening stimulus, compared with when saccades had to be initiated to the opposite location. In addition, if the automatic shift of attention toward the threatening stimulus also results in the automatic programming of a reflexive saccade to that location (as has been shown by the oculomotor capture paradigm; Theeuwes et al., 1998, 1999), then more saccadic errors can be expected when the arrow points toward a neutral rather than a threatening stimulus. We included a control condition with two neutral stimuli to compare saccadic latencies in presence of threat to latencies when no threat was present.

Importantly, since the task instructions require to make saccades in the direction of an endogenous cue, participants were never required to attend to the threatening stimulus to fulfill the task goals. In fact, the task goal was emphasized by requiring participants to make speeded saccades to avoid receiving a shock. Moreover, because participants know that one stimulus is predictive of threat, but do not know exactly when this threat is coming, the fear-conditioned stimuli in our study pose a genuine threat that is most likely considered aversive. Furthermore, because we used stimuli that were controlled for low-level features and complexity, it is ensured that it is the association with fear that drives attention and not low-level feature differences between fear-conditioned and neutral stimuli.

## Experiment 1

### Method

**Ethics statement.** Written consent was obtained from each participant before the experiments. The experiments were approved by the ethics committee of the VU University.

**Participants.** Sixteen naïve students from VU University Amsterdam (10 females, mean age  $22 \pm 3$ ) participated in return

for course credits or cash. All participants reported having normal or corrected-to-normal color vision.

**US calibration.** The experiment started with calibration of the US. The US consisted of a 400 V electric stimulus with duration of 2 ms, delivered to the left ankle. Two electrocardiogram (ECG) electrodes were placed over the tibial nerve at the medial malleolus of the left ankle of participants. Electrodes were connected to a Digitimer DS7A constant current stimulator (Hertfordshire, United Kingdom), which is devised for percutaneous electrical stimulation of subjects in clinical and biomedical research settings. The intensity of the current was calibrated to an “unpleasant but painless” level for each participant individually. Starting at 16 mA, the current was increased stepwise with 4 mA, each time checking with the participant whether the unpleasant but painless level had been reached. When the participant indicated that the stimulus was painful, the current was regulated down. The maximum amperage was 45 mA and calibration ended when this maximum was reached.

**Eye tracking calibration.** Participants were seated 75 cm from a computer screen with their head positioned on a chin rest. Eye movements of the right eye were recorded with an EyeLink 1000 tracker (SR Research Ltd., Canada), with 1,000 Hz temporal and 0.01° spatial resolution. An automatic algorithm detected saccades using minimum velocity and acceleration criteria of 35° per second and 9,500° per square second, respectively. During calibration, participants had to fixate nine calibration dots that were presented randomly in a 3 × 3 grid across the monitor.

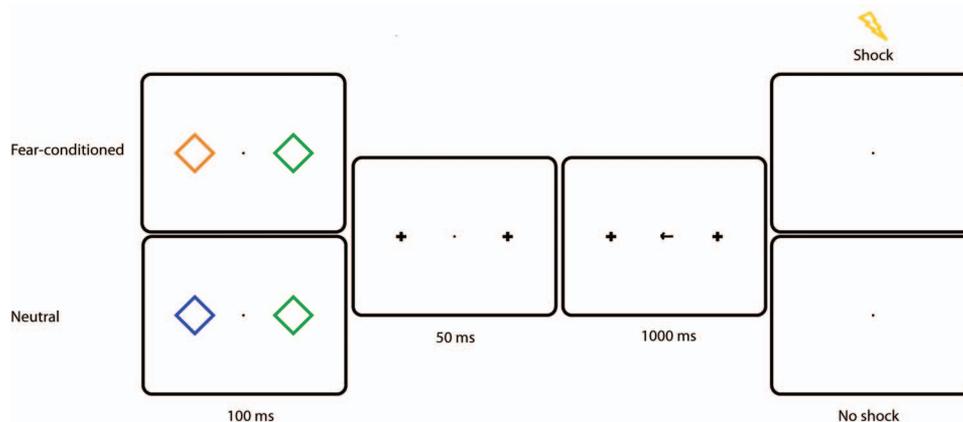
**Stimuli and procedure.** Stimuli were green (CIE:  $x = .300$ ,  $y = .600$ ; 22.39 cd/m<sup>2</sup>), blue (CIE:  $x = .176$ ,  $y = .155$ ; 23.05 cd/m<sup>2</sup>), and orange (CIE:  $x = .542$ ,  $y = .407$ ; 22.75 cd/m<sup>2</sup>) outline diamonds, with sides of 1.74°. Either the blue or orange diamond served as the CS+ and was paired with the US (see below). Stimulus-shock contingencies were counterbalanced across participants.

Each trial started with the presentation of a central fixation cross (0.5° × 0.5°) for a variable time (800–1,300 ms). Afterward, two diamonds appeared on the screen on the horizontal plane at 7° from fixation. One diamond was green, the other was blue or

orange with an equal probability. After 100 ms, the diamonds were replaced by crosses (0.5° × 0.5°), which stayed on the screen throughout the trial. After 50 ms, the central fixation cross was replaced by an arrow that was pointing to the left or to the right with an equal probability (see Figure 1). Participants had to make an eye movement as fast as possible to the location indicated by the arrow. If the saccadic latency exceeded 500 ms, or if the saccadic latency exceeded the average of the previous 10 trials, the text “too slow!” appeared on the screen (0.4° × 1.0°) for 300 ms. In addition, on seven trials in which the CS+ was present and the saccade was executed too slow, the US was delivered at the moment the text disappeared. The probability of receiving a US on those trials was 80%. Once the last shock of the maximum of seven shocks was delivered, the probability of receiving a shock was zero. All participants received a total number of seven shocks during the experiment. To avoid fear extinction after the maximum number of shocks had been reached, participants were not informed of the maximum.

The experiment started with a practice block of 36 trials, in which stimuli with different colors (red, turquoise, and purple) were used. During the practice block, no USs were delivered. After finishing the practice block, participants received verbal instructions about the experimental blocks. They were informed that they only had a chance of receiving a shock when a stimulus of a certain color (i.e., the CS+) was present on the screen. It was emphasized that the shock could be delivered regardless of the location (left or right) of the CS+. Finally, to emphasize that eye movements had to be initiated as fast as possible, participants were told that they could only get a shock when the eye movement latency was slower than the average latency of their previous 10 eye movements. This manipulation ensured that the participants had to make fast saccades on all trials, irrespective of the types of stimuli that were present.

The experimental session consisted of four blocks of 36 trials. Half of the trials contained the fear-conditioned stimulus, the other half contained neutral stimuli. Each block was followed by feedback on speed and accuracy.



*Figure 1.* Example of a trial in the experimental session. Two diamonds were presented left and right from fixation for 100 ms. One of the diamonds was either the CS+ or a neutral stimulus, the other was always a neutral stimulus. After a 50 ms delay, a centrally presented arrow pointed to the left or to the right. Participants had to make a speeded eye movement in that direction. On seven of the CS+ trials, the US was presented after 1,000 ms. See the online article for the color version of this figure.

## Results and Discussion

Trials with saccades faster than 80 ms and slower than 500 ms and saccades that did not start within 1° away from fixation point were excluded from further analyses. This resulted in an average loss of 5.2% of the trials. Saccades that landed within 15° of arc from the center of the valid location were classified as correct. Saccades that landed within 15° of arc from the center of the invalid location were classified as a landing on the wrong location. Trials that were not classified as correct and trials that landed on the wrong location were excluded from RT analyses.

**Saccadic latencies.** Mean saccadic latencies for each condition are shown in Figure 2. Mean saccadic latencies in the neutral condition were used as a baseline. Following the hypothesis, a paired-samples *t* test showed a strong validity effect in the fear-conditioned condition: Saccadic latencies to locations previously occupied by the CS+ were faster (208 ms) than saccadic latencies to the opposite location (232 ms;  $t(15) = 3.774, p < .01, d = .94$ ). To examine whether the validity effect was driven by faster responses to valid locations (i.e., toward the CS+), slower responses to invalid locations (i.e., away from the CS+), or both, we compared saccadic latencies in the fear-conditioned condition to latencies in the neutral condition. Saccades to the CS+ were faster than saccades in the neutral condition (217 ms;  $t(15) = 2.327, p < .05, d = .58$ ), and saccades away from the CS+ were slower than saccades in the neutral condition,  $t(15) = 3.486, p < .01, d = .87$ , indicating latency costs and benefits relative to the neutral condition (see Figure 2).

As a follow-up analysis, we tested if there was a difference in saccadic latencies between the two stimuli in the neutral condition. Unexpectedly, there was small but reliable validity effect: Saccades to locations previously occupied by one of the neutral

stimuli, namely the stimulus that was always presented together with the CS+ in the fear-conditioned condition (i.e., the green diamond in Figure 1), were initiated faster (214 ms) than saccades to the other neutral stimulus (i.e., the blue diamond; 220 ms;  $t(15) = 3.491, p < .01, d = .87$ ), indicating that the neutral stimuli seemed to be not equally neutral to the observers (see below for further explanation).

**Erroneous landings.** On average, 95% of the saccades landed on the correct location. Erroneous landings per condition are shown in Figure 3. Planned comparisons showed that participants made more errors in the invalid fear-conditioned condition (8.9%) than in the valid fear-conditioned (1.6%;  $t(15) = 3.43, p < .01, d = .86$ ) and neutral condition (3.2%;  $t(15) = 3.114, p < .01, d = .78$ ). Thus, participants made erroneous saccades to the location that was previously occupied by the CS+ when they were supposed to make a saccade in the opposite direction.

Following our hypothesis, the results showed that when a potentially threatening stimulus was present, saccades toward its location were faster whereas saccades away from the source of threat were slower relative to the neutral condition. Moreover, more saccadic errors were made when saccades had to be executed to the location opposite of threat. Thus, the presence of threat interfered with the execution of a voluntary saccade. Unexpectedly, we also found a reliable validity effect in the neutral condition in which two supposedly neutral stimuli were presented. At first sight, these trials are assumed to be entirely neutral to the observer because they never predict an aversive outcome. However, because one of the neutral stimuli was always presented along with the fear-conditioned stimulus, this neutral stimulus also predicted the shock in every fear-conditioned trial, causing the neutral stimulus to indirectly acquire fear value. Following this reasoning, the neutral stimulus may have incorrectly signaled threat in the neutral trials, even though these trials were never followed by delivery of a shock.

To further test this possibility and to replicate the results of Experiment 1, we conducted Experiment 2. It consisted of the exact same conditions as Experiment 1, with the addition of a new neutral condition. The neutral condition consisted of two stimuli that never predicted a shock, and were also never presented together with the stimulus that predicted a shock. If stimuli with an indirect as well as a direct fear association indeed attract attention in a similar way, we expect to replicate the effects of Experiment 1. The neutral condition was used to compare saccadic latencies in the presence of threat to latencies when no threat was present.

## Experiment 2

### Method

**Participants.** Sixteen naïve students from VU University Amsterdam (9 females, mean age  $24 \pm 4$ ) participated in return for course credits or cash. All participants reported having normal or corrected-to-normal color vision.

**Stimuli and procedure.** Each participant completed the self-report measure of trait and state anxiety (STAI; Spielberger, 1983) before the experiment.

US calibration and eye tracking calibration were identical to Experiment 1. Stimuli were green, blue, orange, and magenta (CIE:  $x = .321, y = .154; 23.19 \text{ cd/m}^2$ ) outline diamonds with

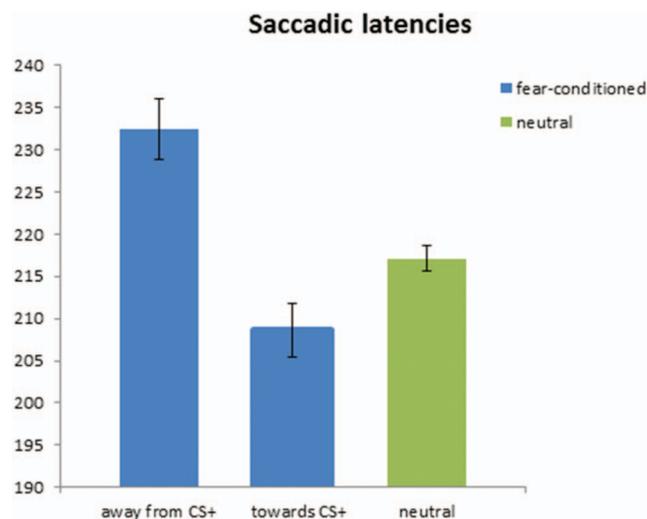


Figure 2. Saccadic latencies per condition. Latencies on invalid fear-conditioned trials (i.e., away from the CS+) were slower than latencies on valid fear-conditioned trials (i.e., away toward the CS+). Latencies to the CS+ were faster compared with the neutral condition and latencies away from the CS+ were slower compared with the neutral condition. Error bars reflect within-subject normalized SEs (Loftus & Masson, 1994). See the online article for the color version of this figure.

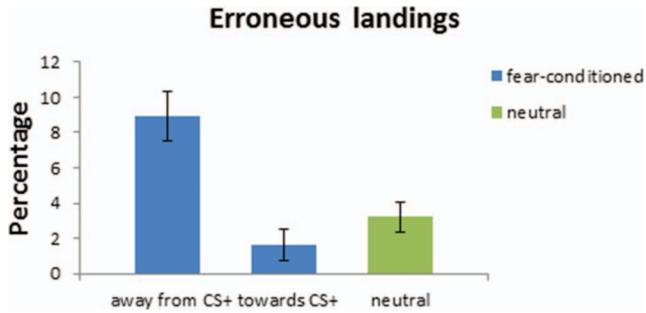


Figure 3. Saccades that landed on the location opposite of the target location. On invalid (i.e., away from the CS+) fear-conditioned trials, more saccades landed on the incorrect location than on any of the other conditions. Error bars reflect within-subject normalized *SEs* (Loftus & Masson, 1994). See the online article for the color version of this figure.

sides of  $1.74^\circ$ . Either the blue or orange diamond served as the CS+ and was paired with the US. Either the green or magenta diamond served as the paired stimulus (PS) and was always presented together with the CS+. Fear-conditioned and paired stimuli were counterbalanced across participants.

The experimental session was similar to Experiment 1, with the addition of an extra condition in which two neutral stimuli were presented together. Thus, there were three possible stimulus pairs: The CS+ together with the PS (“fear-conditioned” condition), the PS together with one of the neutral stimuli (“paired” condition), and two neutral stimuli (“neutral” condition, see Figure 4). The experiment consisted of six blocks of 32 trials. All conditions appeared with an equal probability. All participants received a total number of seven shocks during the experiment.

**Ratings.** After finishing the experimental session, each stimulus was centrally presented on the screen, and participants had to indicate for each stimulus how fearful they were when that stimulus was presented during the experiment. A scale that was labeled from *not at all fearful* (1) to *very fearful* (7) was presented at the bottom of the screen. Participants rated each of the four stimuli by pressing a number from 1 to 7 on the keyboard.

To assess shock expectancy, forced choice trials were included in which two displays were presented side by side. There were four different displays; each containing two stimuli left and right of fixation. The four possible color combinations were orange–green,

blue–green, blue–magenta, and orange–magenta. Three of these displays had been presented in the experiment before (i.e., the fear-conditioned, paired, and neutral display), the fourth was new to the observer. Participants were instructed to choose the display that represented the highest chance of receiving a shock. Each combination of displays was presented twice, so the total number of trials was 12. The location of the displays (left or right of fixation) and order of display presentation was balanced across trials. Participants indicated in which situation the chance of receiving a shock was higher by pressing “1” for the left display or “2” for the right display.

## Results

Trials with saccades faster than 80 ms and slower than 500 ms and saccades that did not start within  $1^\circ$  away from fixation point were excluded from further analyses. This resulted in an average loss of 3.9% of the trials. Saccades that landed within  $15^\circ$  of arc from the center of the target location were classified as correct. Saccades that landed within  $15^\circ$  of arc from the center of the invalid location were classified as a landing on the wrong location. Trials that were not classified as correct and trials that landed on the wrong location were excluded from RT analyses.

**Saccadic latencies.** Mean saccadic latencies for each condition are shown in Figure 5. Mean saccadic latencies in the neutral condition were used as a baseline. A  $2 \times 2$  repeated measurements analysis of variance (ANOVA) on saccadic latencies with condition (fear-conditioned, paired) and validity (valid, invalid) as independent variables revealed a main effect of validity,  $F(1, 15) = 70.499$ ,  $p < .001$ ,  $\eta_p^2 = .83$ . Moreover, there was an interaction effect between condition and validity ( $F(1, 15) = 17.614$ ,  $p < .01$ ,  $\eta_p^2 = .54$ ), indicating that the validity effect was greater on the fear-conditioned trials than on the paired trials. Planned comparisons showed that there was no difference in latencies on valid versus invalid trials in the neutral condition,  $t(15) = 1.760$ ,  $p = .10$ ,  $d = .44$ .

Similar to Experiment 1, planned comparisons showed a strong validity effect in the fear-conditioned condition: Saccadic latencies to locations previously occupied by the CS+ were faster (232 ms) than saccadic latencies to the opposite location (260 ms;  $t(15) = 6.618$ ,  $p < .001$ ,  $d = 1.66$ ). In addition, we again found a validity effect in the paired condition, with faster saccades to locations

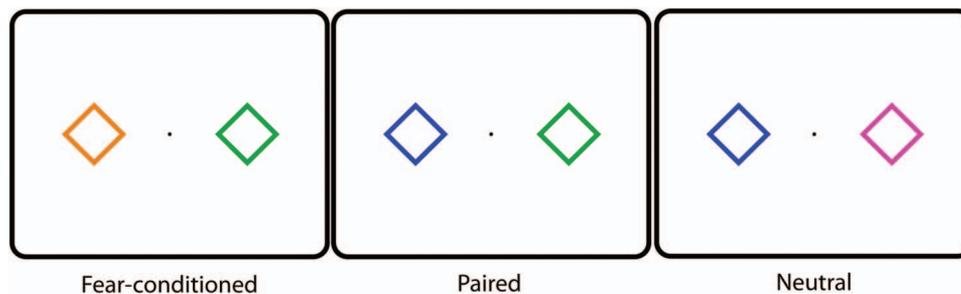
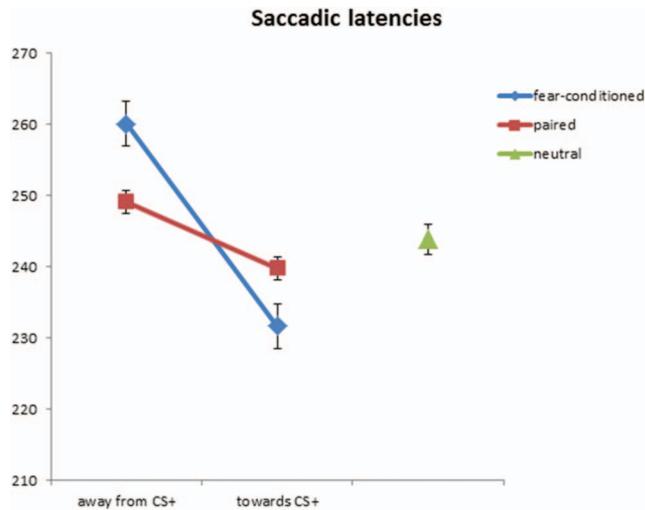


Figure 4. Examples of fear-conditioned, paired, and neutral trials. Only fear-conditioned trials predicted the US. In this example, the orange stimulus served as the CS+ and the green stimulus served as the paired stimulus (PS). See the online article for the color version of this figure.



**Figure 5.** Saccadic latencies per condition. Latencies on invalid (i.e., away from the CS+) fear-conditioned and paired trials were slower compared with neutral trials, and latencies on valid (i.e., toward the CS+) fear-conditioned and paired trials were faster compared with neutral trials. Error bars reflect within-subject normalized *SEs* (Loftus & Masson, 1994). See the online article for the color version of this figure.

previously occupied by the PS (240 ms) than saccades in the opposite direction (249 ms;  $t(15) = 6.616, p < .001, d = 1.65$ ).

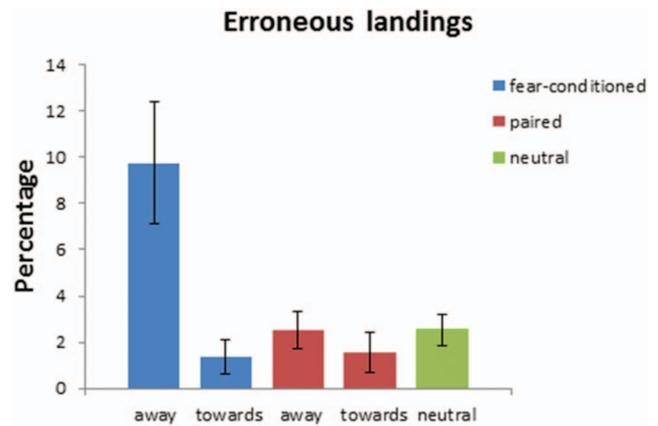
To examine whether the validity effect for the CS+ was driven by faster responses to valid locations, slower responses to invalid locations, or both, we compared saccadic latencies in the fear-conditioned condition to latencies in the neutral condition. Results showed that saccades on valid CS+ trials were faster than saccades on neutral trials (244 ms;  $t(15) = 4.184, p < .01, d = 1.05$ ). In addition, saccades on invalid CS+ trials were slower than saccades on neutral trials,  $t(15) = 3.010, p < .01, d = .75$ .

Similar results were found for the paired condition. Saccades on valid PS trials were faster compared with neutral trials,  $t(15) = 2.219, p < .05, d = .55$ , and saccades on invalid PS trials were slower compared with neutral trials,  $t(15) = 3.725, p < .01, d = .93$ .

**Erroneous landings.** On average, 97% of the saccades landed on the correct location. Erroneous landings per condition are shown in Figure 6. Planned comparisons indicated that participants made more errors on invalid (9.8%) than on valid (1.4%) fear-conditioned trials,  $t(15) = 2.555, p < .01, d = .62$ . Similar to Experiment 1, participants erroneously made saccades to the location that was previously occupied by the CS+ when they were supposed to make a saccade in the opposite direction. This effect was not shown for paired trials (2.5% vs. 1.6%;  $t(15) = 0.565, p < .58, d = .14$ ).

**Questionnaires and ratings.** Participants scored an average of  $35 \pm 12$  on the state part and an average of  $38 \pm 8$  on the trait part of the STAI. To assess the influence of state and trait anxiety on deployment of attention to feared stimuli, correlations between the STAI scores and individual RTs in the fear-conditioned, paired and neutral conditions were calculated. None of the correlations were significant.

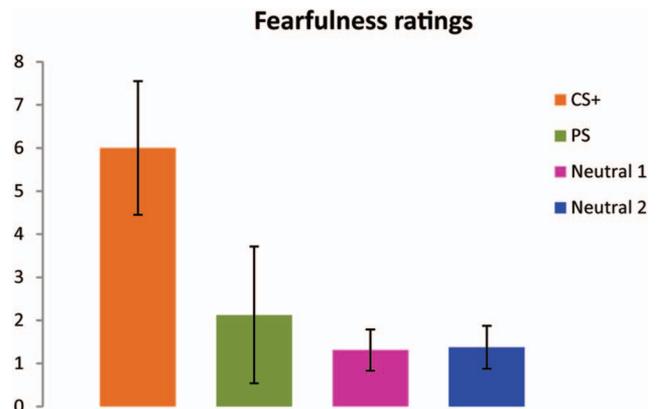
Fear ratings of each stimulus are shown in Figure 7. Paired-samples *t* tests showed that the CS+ was rated as more fearful than



**Figure 6.** Saccades that landed on the location opposite of the target. On invalid fear-conditioned trials (i.e., away from the CS+), more saccades landed on the incorrect location than on any of the other conditions. Error bars reflect within-subject normalized *SEs* (Loftus & Masson, 1994). See the online article for the color version of this figure.

the other stimuli (all  $ps < .001$ ). The PS was rated as slightly more fearful than both the neutral stimuli ( $p = .07$  and  $p = .10$ ). One participant rated all stimuli as “not fearful at all.” Another participant’s rating for the PS was 2 *SDs* above the group mean. Excluding these participants from the analyses did not influence the results.

Results from forced choice trials showed that when the fear-conditioned display was compared with any of the other displays, the fear-conditioned display was rated the highest for the chance of receiving a shock on 100% of the trials. Similarly, when the paired display was compared with the neutral display that was never present during the experiment, the paired display was rated the highest for a chance of receiving a shock on 100% of the trials. Moreover, on trials where the paired display and the neutral display that was present during the experiment were compared, an exact sign test showed that the paired display was rated more often



**Figure 7.** Mean fearfulness ratings for each stimulus. The fear-conditioned stimulus (CS+) was rated as more fearful than the other stimuli. The paired stimulus (PS) was rated as slightly more fearful than the neutral stimuli. Error bars reflect *SDs*. See the online article for the color version of this figure.

as giving the highest chance of receiving a shock (median = 2) compared with the neutral display (median = 0;  $p = .021$ ). Thus, although participants never actually received a shock on the paired trials, their expectancy of receiving a shock was higher than for neutral trials.

### General Discussion

The results of the present study show that a stimulus that signals threat attracts attention and disrupts execution of voluntary saccades to other locations. The main finding of Experiment 1 was that latencies of voluntary saccades were faster when they were made toward fear-conditioned compared with a neutral stimulus. After a brief presentation of two stimuli followed by an endogenous cue, an automatic tendency to look at the fear-conditioned stimulus needed to be actively inhibited to make a voluntary saccade in the opposite direction. Therefore, our results are indicative of a reflexive tendency to attend to potential threat. The results of Experiment 2 replicate the validity effect for the fear-conditioned stimulus, and additionally show that a neutral stimulus that consistently accompanies the threatening stimulus also interferes with saccade execution when combined with a completely neutral stimulus. The validity effect occurred even though the combination of a paired and a neutral stimulus was in fact never combined with a shock.

Most previous studies investigating the effect of threat on attention used either pictorial stimuli (e.g., Nummenmaa, Hyona, & Calvo, 2006, 2009; Ohman, Flykt, et al., 2001) or schematic faces (e.g., Fox et al., 2000; Ohman, Lundqvist, & Esteves, 2001). Although such stimuli can indeed be considered threatening, they only seem to impose a symbolic representation of threat, because they never signal a real aversive outcome. In contrast, fear-conditioned stimuli pose a genuine threat that is very likely to be appraised as aversive. The chance of receiving an electric shock can be considered much more threatening than observing a threatening picture. In addition, studies using pictorial stimuli have less control over the perceptual features. In our study, all stimuli were equally salient in terms of physical appearance, and we can, therefore, assume that the attentional effect was driven by anticipation of fear, and not by low-level feature differences such as complexity, spatial frequency, or luminance.

The pattern of error rates further supports the view that a fear-conditioned stimulus induces a reflexive shift of attention. In situations where participants are instructed to execute a saccade to a specific location, one can speak of reflexive saccades when the eyes move to another location despite this instruction (e.g., Godijn & Theeuwes, 2002). The present study showed that more saccadic errors were made when the arrow pointed toward neutral stimuli compared with the fear-conditioned stimuli. Although the goal of the eye movement was clearly defined, participants could not override the reflexive attention to threat, which eventually resulted in an erroneous saccade toward the location of threat. This may underline a bottom-up influence of the threatening stimuli, and confirms the view that threat attracts visual attention automatically and subsequently biases saccade target selection in a reflexive way.

Because the participants were given the instruction that only the CS+ was predictive of the aversive outcome, it cannot be excluded that the participants voluntarily paid attention to the CS+. However,

our task required that saccades needed to be initiated as fast as possible to avoid receiving the shock. Our data clearly show that the participants' top-down task goal to make fast saccades was overruled by the presence of a threatening stimulus at another location, indicating that the obtained effects index an interference with voluntary saccade programming because of the presence of potential threat.

The validity effects in both the neutral condition in Experiment 1 and the paired condition in Experiment 2 revealed that a neutral stimulus that was always paired with a CS+ also interfered with the execution of a voluntary saccade, when presented together with a neutral stimulus that was never paired with the CS+. Although the effect was smaller than in the CS+ condition, saccades to the paired stimulus were faster relative to saccades away from the PS. The fact that the PS elicits similar behavior as the CS+ is in line with well-known types of classical conditioning such as compound or contextual conditioning (e.g., Rudy, Huff, & Matus-Amat, 2004; Urcelay & Miller, 2014; Witnauer & Miller, 2011). In contextual conditioning, two or more stimuli are presented together and consequently form a compound CS. For example, when the dog in Pavlov's laboratory heard a tone CS, it was probably also sensing to greater or lesser extent the visual, auditory, and other stimuli that were present at the time. Although contextual stimuli are always present and are therefore by themselves never predictive of the US, they are obviously part of the compound CS that is associated with the US (Fanselow, 1990; Helmstetter & Fanselow, 1989). Therefore, it can be argued that contextual stimuli are predictive of the general situation in which the US is likely to occur, but are not predictive of the onset of the particular US (Phillips & Ledoux, 1992).

Following this line of reasoning, the PS in our experiment most likely acquired an associative value with each pairing of CS and US, and subsequently attracted attention when presented together with a completely neutral stimulus. Because the compound CS+/PS was predicting a chance of an aversive event, the predictive value of the PS was just as high as the predictive value of the CS+ in fear-conditioned trials. However, in neutral trials, the predictive value of the PS was ambiguous and could only be inferred, because the PS was in that situation never combined with the US. Still, in the neutral condition, the predictive threat value of the PS was obviously relatively high when it competed for attention with a completely neutral stimulus. Therefore, attention was drawn toward the PS when presented together with a completely neutral stimulus. The differences in threat predictability are confirmed by the participants' ratings of shock expectancy. When asked whether the CS+/PS or the PS/Neutral compound elicited a higher expectancy of receiving a shock, participants had a higher expectancy for the CS+/PS compound. In addition, the PS/Neutral compound provided a higher expectancy of the shock than the Neutral/Neutral compound, even though none of these trials were ever combined with the shock. The fearfulness ratings show that when the stimuli are presented alone and are not part of a compound, fear for the CS+ was clearly higher compared with the paired and neutral stimuli. The paired stimulus is rated as just slightly more fearful than the neutral stimuli, indicating that participants tended to learn a fear association between the PS and the aversive outcome.

It is possible that the instruction given to the participants about which stimulus predicts a shock is responsible for the effects

observed. Following this logic, the CS+ competed for attention not because it was threatening but because it was a stimulus conveying important information. Even though feasible, we do not think that this is likely, because the PS in our study produced effects similar to the CS+. No instructions were given about the PS, and it acquired its priority status only through the process of classical conditioning. Furthermore, at the end of the experiment participants rated both the CS+ and the PS as threatening, and it is highly unlikely that instructions alone were responsible for this. We believe it is the shock associated with the stimulus that drives this effect. In our view, the competition for attention is because of the likelihood of receiving an electrical shock. When competing for attention, the fear-conditioned stimulus wins from the paired stimulus and attracts attention because it has the highest predictive value for threat (i.e., around 10% of all trials where the CS+ was present vs. around 5% of all trials where the PS was present). For the same reason, the paired stimulus wins from the neutral stimulus in the neutral condition (5% vs. 0%). Clearly, the CS+ was the strongest predictor of threat and hence more effective as CS, as reflected in the difference in magnitude of the validity effects.

The current results provide clear evidence that potential threat influences attention as a result of associations between an initially neutral stimulus and an aversive outcome. Covert attention is initially directed to fear-conditioned stimuli, which then guides overt attention toward them. It has been argued that these threat-related attentional processes have fundamental survival value because of their clear evolutionary value (e.g., Mogg & Bradley, 1998). Fear-conditioned stimuli are thought to be enhanced directly via a subcortical pathway through the superior colliculus and pulvinar to the amygdala (e.g., Alpers, Ruhleder, Walz, Muhlberger, & Pauli, 2005). Using fear-conditioned emotional faces as spatial cues, Armony and Dolan (2002) demonstrated that the modulation of attention by fear-conditioned emotional faces involves an interplay between the fronto-parietal neural network, which is thought to underlie the control of spatial attention, and the lateral orbitofrontal cortex (IOFC). The authors argued that the IOFC can receive information about the affective value of a stimulus from the amygdala to cortical areas involved in spatial attention. The shift of attention to potential threat in our study suggests that initially neutral stimuli that are fear-conditioned may be processed in a similar way. However, whether a fast-track connection between the amygdala and cortical structures exists in the human brain is still under debate (de Gelder, van Honk, & Tamietto, 2011; Pessoa & Adolphs, 2010).

Previous studies already showed diverse effects of fear-conditioned stimuli on attention. Most studies measured manual responses and found interference of selection of neutral targets in presence of a fear-conditioned stimulus at another location (Schmidt et al., 2014; Van Damme et al., 2008). Our data extend these results by showing that the presence of threat interferes with the execution of an eye movement in another direction. More important, we also show that the speed of initiating a saccade to the location of threat is facilitated compared with neutral locations. In contrast to manual responses, which are a more indirect way of measuring allocation of attention, eye movements provide a more biologically relevant measure in which orienting of attention is measured directly. Consistent with our findings, fast orienting to pictorial representations of threat is often observed in studies using eye movements (e.g., Bannerman et al., 2009, 2010; Nummenmaa

et al., 2009). Furthermore, the use of eye movements allowed us to measure erroneous reflexive responses to locations of threat, which confirms the view that threat attracts visual attention automatically. So far, only Mulckhuysse and colleagues (2013) investigated eye movements in relation to fear-conditioned stimuli. In their study, a saccade had to be executed toward a neutral target in presence of a fear-conditioned or a neutral distractor. While the competition by the fear-conditioned distractor was reflected in the eyes curving away from its location, its presence did not increase saccadic latency and did not elicit erroneous saccades to its location. Our study demonstrated that the threatening stimulus strongly competes with a goal-directed eye movement by evoking programming of involuntary eye movement to its location. This is reflected in faster initiation of saccades to its location, but also by the difficulty of suppressing eye movements to its location.

We believe that there are two important aspects of our design that allowed us to observe such strong competition from the fear-conditioned stimulus. First, unlike most previous studies using fear-conditioning approach, a genuine threat of shock was maintained throughout the whole experiment. Second, we have ensured that participants made very fast eye movements. Because the programming of involuntary eye movement has a transient time-course, the competition from the threatening stimulus is likely to dissipate very quickly and possibly suppressed (as in Mulckhuysse et al., 2013).

Although the attentional prioritization of threat is clearly relevant because of its evolutionary importance, it has been shown that automatic modulation of attention is not specific to threat. Several studies have for example shown that stimuli that are associated with a monetary reward also cause attentional and oculomotor capture (Anderson, Laurent, & Yantis, 2011; Failing & Theeuwes, 2014; Theeuwes & Belopolsky, 2012). Therefore, it can be argued that the amygdala may act as a general detector of behavioral relevant stimuli, such as stimuli that are novel, surprising, or sad (Ousdal et al., 2008). The amygdala detects and processes information about potentially relevant stimuli and their relationship to an individual's current goals or needs (Sander, Grafman, & Zalla, 2003). Because goals and needs vary between individuals and over time, the amygdala response to a certain stimulus is variable. For example, differential amygdala responses to food stimuli have been demonstrated in states of hunger and satiety (e.g., Gottfried, O'Doherty, & Dolan, 2003). The modulation of attention in our study may, therefore, also be observed when cues with a different behavioral value are present, in situations where those cues are relevant for the participant's present goals. However, the significance of behaviorally relevant cues may originate from different motivations. For example, whereas reward-related items may increase the motivation to obtain them, fear-related objects may increase the motivation to avoid them (e.g., Ford et al., 2010).

Obviously, our results do not provide insights in what happens after the threat has been localized and an appropriate behavioral response has to be selected. Some studies say that once attended, threatening stimuli are also difficult to disengage from because threat in the environment needs to be monitored (e.g., Belopolsky, Devue, & Theeuwes, 2011). Alternatively, the "vigilance-avoidance" hypothesis (Mogg, Bradley, Miles, & Dixon, 2004) would predict that an initial capture of attention by threatening stimuli is followed by a tendency to avoid them. Future studies

could investigate behavioral responses to threatening stimuli after the quick initial orienting.

In summary, our research indicates that in situations where two stimuli compete for attentional selection, potentially threatening stimuli are prioritized and interfere with the experimentally imposed, top-down target selection. Even though the stimuli were initially neutral and equally salient, attention automatically shifted to the location of the fear-conditioned stimulus and biased overt behavior.

## References

- Alpers, G. W., Ruhleder, M., Walz, N., Mühlberger, A., & Pauli, P. (2005). Binocular rivalry between emotional and neutral stimuli: A validation using fear conditioning and EEG. *International Journal of Psychophysiology*, *57*, 25–32. <http://dx.doi.org/10.1016/j.ijpsycho.2005.01.008>
- Anderson, B. A., Laurent, P. A., & Yantis, S. (2011). Learned value magnifies salience-based attentional capture. *PLoS ONE*, *6*, e27926. <http://dx.doi.org/10.1371/journal.pone.0027926>
- Armony, J. L., & Dolan, R. J. (2002). Modulation of spatial attention by fear-conditioned stimuli: An event-related fMRI study. *Neuropsychologia*, *40*, 817–826. [http://dx.doi.org/10.1016/S0028-3932\(01\)00178-6](http://dx.doi.org/10.1016/S0028-3932(01)00178-6)
- Bannerman, R. L., Milders, M., de Gelder, B., & Sahraie, A. (2009). Orienting to threat: Faster localization of fearful facial expressions and body postures revealed by saccadic eye movements. *Proceedings of the Royal Society B: Biological Sciences*, *276*, 1635–1641. <http://dx.doi.org/10.1098/rspb.2008.1744>
- Bannerman, R. L., Milders, M., & Sahraie, A. (2010). Attentional bias to brief threat-related faces revealed by saccadic eye movements. *Emotion*, *10*, 733–738. <http://dx.doi.org/10.1037/a0019354>
- Becker, D. V., Anderson, U. S., Mortensen, C. R., Neufeld, S. L., & Neel, R. (2011). The face in the crowd effect unconfounded: Happy faces, not angry faces, are more efficiently detected in single- and multiple-target visual search tasks. *Journal of Experimental Psychology: General*, *140*, 637–659. <http://dx.doi.org/10.1037/a0024060>
- Belopolsky, A. V., Devue, C., & Theeuwes, J. (2011). Angry faces hold the eyes. *Visual Cognition*, *19*, 27–36. doi. Pii, 931450479.
- Belopolsky, A. V., & Theeuwes, J. (2012). Updating the premotor theory: The allocation of attention is not always accompanied by saccade preparation. *Journal of Experimental Psychology: Human Perception and Performance*, *38*, 902–914. <http://dx.doi.org/10.1037/a0028662>
- de Gelder, B., van Honk, J., & Tamietto, M. (2011). Emotion in the brain: Of low roads, high roads and roads less travelled. *Nature Reviews Neuroscience*, *12*, 425. <http://dx.doi.org/10.1038/nrn2920-c1>
- Eftting, M., & Kindt, M. (2007). Contextual control of human fear associations in a renewal paradigm. *Behaviour Research and Therapy*, *45*, 2002–2018. <http://dx.doi.org/10.1016/j.brat.2007.02.011>
- Egeth, H. E., & Yantis, S. (1997). Visual attention: Control, representation, and time course. *Annual Review of Psychology*, *48*, 269–297. <http://dx.doi.org/10.1146/annurev.psych.48.1.269>
- Failing, M. F., & Theeuwes, J. (2014). Exogenous visual orienting by reward. *Journal of Vision*, *14*, 6. <http://dx.doi.org/10.1167/14.5.6>
- Fanselow, M. S. (1990). Factors governing one-trial contextual conditioning. *Animal Learning & Behavior*, *18*, 264–270. <http://dx.doi.org/10.3758/BF03205285>
- Ford, B. Q., Tamir, M., Brunyé, T. T., Shirer, W. R., Mahoney, C. R., & Taylor, H. A. (2010). Keeping your eyes on the prize: Anger and visual attention to threats and rewards. *Psychological Science*, *21*, 1098–1105. <http://dx.doi.org/10.1177/0956797610375450>
- Fox, E., Lester, V., Russo, R., Bowles, R. J., Pichler, A., & Dutton, K. (2000). Facial expressions of emotion: Are angry faces detected more efficiently? *Cognition and Emotion*, *14*, 61–92. <http://dx.doi.org/10.1080/026999300378996>
- Fox, E., Russo, R., Bowles, R., & Dutton, K. (2001). Do threatening stimuli draw or hold visual attention in subclinical anxiety? *Journal of Experimental Psychology: General*, *130*, 681–700. <http://dx.doi.org/10.1037/0096-3445.130.4.681>
- Godijn, R., & Theeuwes, J. (2002). Programming of endogenous and exogenous saccades: Evidence for a competitive integration model. *Journal of Experimental Psychology: Human Perception and Performance*, *28*, 1039–1054. <http://dx.doi.org/10.1037/0096-1523.28.5.1039>
- Gottfried, J. A., O'Doherty, J., & Dolan, R. J. (2003). Encoding predictive reward value in human amygdala and orbitofrontal cortex. *Science*, *301*, 1104–1107. <http://dx.doi.org/10.1126/science.1087919>
- Helmstetter, F. J., & Fanselow, M. S. (1989). Differential second-order aversive-conditioning using contextual stimuli. *Animal Learning & Behavior*, *17*, 205–212. <http://dx.doi.org/10.3758/BF03207636>
- Hunt, A. R., Cooper, R. M., Hung, C., & Kingstone, A. (2007). The effect of emotional faces on eye movements and attention. *Visual Cognition*, *15*, 513–531. <http://dx.doi.org/10.1080/13506280600843346>
- Kissler, J., & Keil, A. (2008). Look-don't look! How emotional pictures affect pro- and anti-saccades. *Experimental Brain Research*, *188*, 215–222. <http://dx.doi.org/10.1007/s00221-008-1358-0>
- Koster, E. H., Crombez, G., Van Damme, S., Verschuere, B., & De Houwer, J. (2004). Does imminent threat capture and hold attention? *Emotion*, *4*, 312–317. <http://dx.doi.org/10.1037/1528-3542.4.3.312>
- LeDoux, J. E. (1996). *The emotional brain*. New York, NY: Simon & Schuster.
- Lipp, O. V., Derakshan, N., Waters, A. M., & Logies, S. (2004). Snakes and cats in the flower bed: Fast detection is not specific to pictures of fear-relevant animals. *Emotion*, *4*, 233–250. <http://dx.doi.org/10.1037/1528-3542.4.3.233>
- Lipp, O. V., & Waters, A. M. (2007). When danger lurks in the background: Attentional capture by animal fear-relevant distractors is specific and selectively enhanced by animal fear. *Emotion*, *7*, 192–200. <http://dx.doi.org/10.1037/1528-3542.7.1.192>
- Loftus, G. R., & Masson, M. E. J. (1994). Using confidence intervals in within-subject designs. *Psychonomic Bulletin and Review*, *1*, 476–490. <http://dx.doi.org/10.3758/BF03210951>
- Miltner, W. H., Krieschel, S., Hecht, H., Trippe, R., & Weiss, T. (2004). Eye movements and behavioral responses to threatening and nonthreatening stimuli during visual search in phobic and nonphobic subjects. *Emotion*, *4*, 323–339. <http://dx.doi.org/10.1037/1528-3542.4.4.323>
- Mogg, K., & Bradley, B. P. (1998). A cognitive-motivational analysis of anxiety. *Behaviour Research and Therapy*, *36*, 809–848. [http://dx.doi.org/10.1016/S0005-7967\(98\)00063-1](http://dx.doi.org/10.1016/S0005-7967(98)00063-1)
- Mogg, K., Bradley, B. P., Miles, F., & Dixon, R. (2004). Time course of attentional bias for threat scenes: Testing the vigilance-avoidance hypothesis. *Cognition and Emotion*, *18*, 689–700. <http://dx.doi.org/10.1080/0269993041000158>
- Mulckhuyse, M., Crombez, G., & Van der Stigchel, S. (2013). Conditioned fear modulates visual selection. *Emotion*, *13*, 529–536. <http://dx.doi.org/10.1037/a0031076>
- Notebaert, L., Crombez, G., Van Damme, S., De Houwer, J., & Theeuwes, J. (2011). Signals of threat do not capture, but prioritize, attention: A conditioning approach. *Emotion*, *11*, 81–89. <http://dx.doi.org/10.1037/a0021286>
- Nummenmaa, L., Hyönä, J., & Calvo, M. G. (2006). Eye movement assessment of selective attentional capture by emotional pictures. *Emotion*, *6*, 257–268.
- Nummenmaa, L., Hyönä, J., & Calvo, M. G. (2009). Emotional scene content drives the saccade generation system reflexively. *Journal of Experimental Psychology: Human Perception and Performance*, *35*, 305–323. <http://dx.doi.org/10.1037/a0013626>
- Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology: General*, *130*, 466–478. <http://dx.doi.org/10.1037/0096-3445.130.3.466>

- Öhman, A., Lundqvist, D., & Esteves, F. (2001). The face in the crowd revisited: A threat advantage with schematic stimuli. *Journal of Personality and Social Psychology, 80*, 381–396. <http://dx.doi.org/10.1037/0022-3514.80.3.381>
- Ousdal, O. T., Jensen, J., Server, A., Hariri, A. R., Nakstad, P. H., & Andreassen, O. A. (2008). The human amygdala is involved in general behavioral relevance detection: Evidence from an event-related functional magnetic resonance imaging Go-NoGo task. *Neuroscience, 156*, 450–455. <http://dx.doi.org/10.1016/j.neuroscience.2008.07.066>
- Pavlov, I. P. (1927). *Conditioned reflexes: An investigation of the physiological activity of the cerebral cortex*. London: Oxford University Press.
- Pessoa, L., & Adolphs, R. (2010). Emotion processing and the amygdala: From a 'low road' to 'many roads' of evaluating biological significance. *Nature Reviews Neuroscience, 11*, 773–783. <http://dx.doi.org/10.1038/nrn2920>
- Phillips, R. G., & LeDoux, J. E. (1992). Differential contribution of amygdala and hippocampus to cued and contextual fear conditioning. *Behavioral Neuroscience, 106*, 274–285. <http://dx.doi.org/10.1037/0735-7044.106.2.274>
- Pischeck-Simpson, L. K., Boschen, M. J., Neumann, D. L., & Waters, A. M. (2009). The development of an attentional bias for angry faces following Pavlovian fear conditioning. *Behaviour Research and Therapy, 47*, 322–330. <http://dx.doi.org/10.1016/j.brat.2009.01.007>
- Rinck, M., Becker, E. S., Kellermann, J., & Roth, W. T. (2003). Selective attention in anxiety: Distraction and enhancement in visual search. *Depression and Anxiety, 18*, 18–28. <http://dx.doi.org/10.1002/da.10105>
- Rinck, M., Reinecke, A., Ellwart, T., Heuer, K., & Becker, E. S. (2005). Speeded detection and increased distraction in fear of spiders: Evidence from eye movements. *Journal of Abnormal Psychology, 114*, 235–248. <http://dx.doi.org/10.1037/0021-843X.114.2.235>
- Rizzolatti, G., Riggio, L., Dascola, I., & Umiltá, C. (1987). Reorienting attention across the horizontal and vertical meridians: Evidence in favor of a premotor theory of attention. *Neuropsychologia, 25*(1A), 31–40. [http://dx.doi.org/10.1016/0028-3932\(87\)90041-8](http://dx.doi.org/10.1016/0028-3932(87)90041-8)
- Rudy, J. W., Huff, N. C., & Matus-Amat, P. (2004). Understanding contextual fear conditioning: Insights from a two-process model. *Neuroscience and Biobehavioral Reviews, 28*, 675–685. <http://dx.doi.org/10.1016/j.neubiorev.2004.09.004>
- Sander, D., Grafman, J., & Zalla, T. (2003). The human amygdala: An evolved system for relevance detection. *Reviews in the Neurosciences, 14*, 303–316. <http://dx.doi.org/10.1515/REVNEURO.2003.14.4.303>
- Schmidt, L. J., Belopolsky, A. V., & Theeuwes, J. (2012). The presence of threat affects saccade trajectories. *Visual Cognition, 20*, 284–299. <http://dx.doi.org/10.1080/13506285.2012.658885>
- Schmidt, L. J., Belopolsky, A. V., & Theeuwes, J. (2014). Attentional capture by signals of threat. *Cognition and Emotion*. Advance online publication. <http://dx.doi.org/10.1080/02699931.2014.924484>
- Soares, S. C., Esteves, F., Lundqvist, D., & Ohman, A. (2009). Some animal specific fears are more specific than others: Evidence from attention and emotion measures. *Behaviour Research and Therapy, 47*, 1032–1042. <http://dx.doi.org/10.1016/j.brat.2009.07.022>
- Spielberger, C. D., Gorsuch, R. L., Lushene, R., Vagg, P. R., & Jacobs, G. A. (1983). *Manual for the State-Trait Anxiety Inventory*. Palo Alto, CA: Consulting Psychologists Press.
- Stormark, K. M., & Hugdahl, K. (1996). Peripheral cuing of covert spatial attention before and after emotional conditioning of the cue. *International Journal of Neuroscience, 86*, 225–240. <http://dx.doi.org/10.3109/00207459608986713>
- Stormark, K. M., Hugdahl, K., & Posner, M. I. (1999). Emotional modulation of attention orienting: A classical conditioning study. *Scandinavian Journal of Psychology, 40*, 91–99. <http://dx.doi.org/10.1111/1467-9450.00104>
- Theeuwes, J. (1991). Exogenous and endogenous control of attention: The effect of visual onsets and offsets. *Perception & Psychophysics, 49*, 83–90. <http://dx.doi.org/10.3758/BF03211619>
- Theeuwes, J. (1992). Perceptual selectivity for color and form. *Perception & Psychophysics, 51*, 599–606. <http://dx.doi.org/10.3758/BF03211656>
- Theeuwes, J. (2010). Top-down and bottom-up control of visual selection. *Acta Psychologica, 135*, 77–99. <http://dx.doi.org/10.1016/j.actpsy.2010.02.006>
- Theeuwes, J., & Belopolsky, A. V. (2012). Reward grabs the eye: Oculomotor capture by rewarding stimuli. *Vision Research, 74*, 80–85. <http://dx.doi.org/10.1016/j.visres.2012.07.024>
- Theeuwes, J., Kramer, A. F., Hahn, S., & Irwin, D. E. (1998). Our eyes do not always go where we want them to go: Capture of the eyes by new objects. *Psychological Science, 9*, 379–385. <http://dx.doi.org/10.1111/1467-9280.00071>
- Theeuwes, J., Kramer, A. F., Hahn, S., Irwin, D. E., & Zelinsky, G. J. (1999). Influence of attentional capture on oculomotor control. *Journal of Experimental Psychology: Human Perception and Performance, 25*, 1595–1608. <http://dx.doi.org/10.1037/0096-1523.25.6.1595>
- Urcelay, G. P., & Miller, R. R. (2014). The functions of contexts in associative learning. *Behavioural Processes, 104*, 2–12. <http://dx.doi.org/10.1016/j.beproc.2014.02.008>
- Van Damme, S., Crombez, G., & Notebaert, L. (2008). Attentional bias to threat: A perceptual accuracy approach. *Emotion, 8*, 820–827. <http://dx.doi.org/10.1037/a0014149>
- Vuilleumier, P. (2005). How brains beware: Neural mechanisms of emotional attention. *Trends in Cognitive Sciences, 9*, 585–594. <http://dx.doi.org/10.1016/j.tics.2005.10.011>
- Witnauer, J. E., & Miller, R. R. (2011). The role of within-compound associations in learning about absent cues. *Learning & Behavior, 39*, 146–162. <http://dx.doi.org/10.3758/s13420-010-0013-3>
- Yantis, S. (1996). On the continuity of perceptual experience: Implications for perception and attention. *Canadian Psychology, 37*, 61. <http://dx.doi.org/10.1037/h0084732>

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