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Signals of threat do not capture, but prioritize, attention: A conditioning approach

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Signals of threat do not capture, but prioritize attention: a classical conditioning approach

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Abstract

Research suggests that threatening information captures attention more rapidly than neutral information. However, in most studies threat stimuli differ perceptually from neutral stimuli and are instrumental to perform the task, leaving the question unanswered whether threat is sufficient to capture attention. In Experiment 1, we designed a visual search task with stimuli of equal salience (colored circles) that have the potential to lead to efficient search (10 ms/item). In Experiment 2, one of the colors (Conditioned Stimulus, CS+) was made threatening by means of fear-conditioning. Participants responded to a target presented in one of the circles. Overall, search was faster on congruent trials (where the target was presented in the CS+) than on baseline trials (where the CS+ was absent). Furthermore, search was slower on incongruent trials (where the target was presented in another color than the CS+) than on baseline trials. Search on congruent trials was affected by set size (90 ms/item), but to a lesser extent than on baseline trials (105 ms/item). We conclude that threat prioritizes, but does not capture attention.

Keywords: Visual Search, Anxiety, Capture, Attentional Bias, Fear Conditioning

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Imagine two male Homo Sapiens in their natural habitat, consisting of some bushes, trees, and a small camp. Suddenly, barely audible, a bush nearby the men rustles. One of the men cocks his ears and turns his head in the direction of the noise, while the other man just trudges on. When a lion leaps from the bush ready to attack, the first man has just enough time to run for his life. The second man, however, surprised by the sudden charge, is now a tasty meal. Having an attentional bias to threat is of obvious importance. By showing this bias, the first man gained an evolutionary benefit over the second man. Therefore it is plausible that this ability is subject to natural selection, thereby increasing its incidence in the population. This way, an “evolved fear module” (Öhman & Mineka, 2001) may have arisen that allows people to quickly orient to, detect and react to threatening stimuli.

The selection of threatening information at the expense of other information seems to be a ubiquitous phenomenon. Such an attentional bias to threat is well-established in patients with a psychiatric diagnosis of phobia or an anxiety disorder, and in people with a general disposition to experience fear and distress (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, IJzendoorn, 2007). Studies using emotional adaptations of the Stroop task (Stroop, 1935) have generally found that words with a negative, threatening meaning interfere with the naming of the color of these words (MacLeod, 1991). Whereas the interpretation of Stroop interference in terms of attention has been criticized (De Ruiter & Brosschot, 1994), studies using the dot probe paradigm

(MacLeod, Mathews & Tata, 1986) have further substantiated the phenomenon. In the dot-probe task, two cues (for example pictures) are simultaneously presented on a computer screen for a brief time interval after which a dot is presented at the location of one of the cues. Participants are asked to respond to the location of the dot. Studies that have employed threatening and neutral pictures found faster reaction times on congruent trials (where the dot is presented at the location of the threatening picture) than on incongruent trials (where the dot is presented at the location of a neutral picture; MacLeod et al., 1986; Mogg & Bradley, 1999). These results are often interpreted as evidence in support of a rapid attentional capture by threat (Mathews, Mackintosh & Fulcher, 1997). There are, however, problems with such an interpretation.

First, most studies using the dot probe paradigm fail to differentiate between rapid capture of attention by threat and a difficulty to disengage attention from threat once detected (see Fox, Russo, Bowles, & Dutton, 2001; Theeuwes & Van der Stigchel, 2006). Studies that did differentiate between these two attentional components found – surprisingly– that an attentional bias to threatening information is characterized by a difficulty disengaging attention from threat rather than by a swift capture of attention by threat (Koster, Crombez, Verschuere, & De Houwer, 2004). The results of studies using a spatial cueing paradigm, in which only one cue instead of two is presented, are in line with this conclusion. Anxious individuals show no effect on the initial capture of attention by the threatening information, but rather a pronounced difficulty disengaging attention from threatening information (Yiend & Mathews, 2001; Fox et al., 2001). The only studies that have found (albeit small) effects of initial capture by threat are studies that used conditioned threatening stimuli (e.g. Koster, Crombez, Van Damme, Verschuere, &

De Houwer, 2004; Van Damme, et al., 2004). It is possible that these studies show an underestimation of this initial capture by threat (Mogg, Holmes, Garner & Bradley, 2008; Van Damme, Crombez & Notebaert, 2008). For example, the onset of the presentation of the only cue present in a spatial cuing paradigm may already be sufficient to capture attention (Yantis & Jonides, 1984), hence leaving almost no opportunity for a supplementary facilitation by threat (Fox et al., 2001).

Second, and more importantly, the capture of attention by threatening information is probably best investigated in experimental paradigms with a varying number of competing stimuli (Frischen, Eastwood, & Smilek, 2008). This can be done in visual search paradigms, in which participants localize and identify a target among a varying number of distractors. In the domain of visual attention, a stimulus is said to capture attention, or in other words to pop out, when it produces flat search slopes (a reaction time increase of less than 10 ms per additional distractor) (Treisman & Gelade, 1980). Various features in the domain of visual attention have been reported to fulfil this criterion (e.g. color: Bundesen & Pedersen, 1983; motion: Dick, Ullman & Sagi, 1987).

It has been argued that threat may also be one of those unique features that capture attention (Batty, Cave, & Pauli, 2005). To this end, the visual search paradigm has been adapted to examine whether or to what extent the detection of threatening information is affected by the number of other simultaneously presented stimuli. For example, Öhman, Flykt and Esteves (2001) found that searching for a threatening target (spider or snake) among neutral distractors (flowers or mushrooms) led to a flat search slope. Similarly, it has been claimed that angry faces produce flat search slopes when embedded in neutral face distractors (e.g. White, 1995). However, some reviews are skeptical about this claim. Indeed, the available evidence on attentional capture by threatening stimuli in visual search tasks shows large heterogeneity in results (Frischen et al., 2008; Horstmann, 2009), and there are two further problems. First, it remains unclear whether the threat value of stimuli was critical for the effects observed (Cave & Batty, 2006). It may well be that the threatening stimuli and neutral stimuli differ in a number of unique perceptual features (e.g. luminance and shape), allowing participants to strategically use these features in their search for the target (Cave & Batty, 2006; Tipples, Young, Quinlan, Broks, & Ellis, 2002). This issue has been recognized as a major problem (Frischen et al., 2008). Second, in most of the aforementioned studies the threatening stimulus is instrumental to the task, and participants may intentionally look for this threatening stimulus (e.g. Öhman, Flykt et al., 2001). If threat really is a distinctive feature that captures attention, capture should also be evident when the threatening stimulus is task-irrelevant. Indeed, in the domain of visual attention, capture is investigated in paradigms where the stimulus or feature that captures attention is not the same as the target that the participant is searching for (e.g. Theeuwes, 1995; Yantis & Egeth, 1999). An adaptation of the visual search paradigm in which attention to threatening information is not instrumental for the task at hand would be helpful in ruling out such an explanation. An adaptation like this would not only be a methodological improvement, but would also be theoretically relevant. Indeed, attention to threatening information is often regarded as an unintentional process (McNally, 1995; Crombez, Van Damme, & Eccleston, 2005).

Taking into account the two above-mentioned issues, we aimed to investigate whether threat captures attention. First, in order to have experimental control over the perceptual features and the threat value of the stimuli, we used a classical conditioning procedure and simple visual stimuli (colored circles). One of the colors repeatedly co-occurred with an aversive, painful electrocutaneous stimulus. Second, we made the signal of threat unpredictive for the target by separating the threat value of a stimulus (color of the circle) from its task-relevance (target is a line segment in one of the circles). Consequently, target detection is unlikely to be based on a strategic or intentional threat-based search strategy. An additional benefit of this design is that it allows differentiating between the facilitative effect of threat (congruent trials, where the threatening stimulus is at the same location as the target) and the interfering effect of threat (incongruent trials, where the threatening stimulus is at a different location than the target).

We had two hypotheses in mind. First, if threat captures attention, we hypothesized to find a faster detection of the target when it is presented at the same location as the threatening stimulus (congruent trials) than when no threatening stimulus is presented (baseline trials), and flat search slopes (no reaction time increase with an increasing number of distractors) on the congruent trials. Mutatis mutandis, we hypothesized to find a slower detection of the target when it is presented at a different location than the threatening stimulus (incongruent trials) in comparison with baseline trials. We call this view the “capture hypothesis”. However, Frischen et al. (2008) noted that visual search is rarely under complete control of pre-attentive (stimulus driven) processing allowing pop out. On the contrary, attentional guidance is likely to be the result of a combination of both affective and perceptual characteristics of the stimuli, which makes it difficult to establish a pop out effect purely based on the emotional valence of a stimulus. Hence, it is important to compare search slopes of emotional and neutral stimuli relative to each other. Thus, the second view is that detection of the target on congruent trials will lead to a flatter search slope than on baseline trials (where the CS+ is not present), but not to a flat slope (see also Gerritsen, Frischen, Blake, Smilek & Eastwood, 2008). Also here, we expected a slower detection of targets on incongruent trials than on baseline trials. We call this view the "priority hypothesis".

Because this is a new paradigm, we wanted to demonstrate in Experiment 1 that our stimuli and procedure have the potential to cause a flat search slope (or pop out). After all, it is important to test whether the colored circles are sufficiently visible and salient to attract attention (i.e., produce flat search slopes). If this is not the case, a threat-related color can probably never lead to pop out (see also LeDoux, 1998).

Experiment 1

We hypothesized that an intentional search for a target stimulus that was embedded in one particular colored circle, would result in a flat search slope (pop out). To this end, participants performed a visual search task in two conditions. In both conditions, no threatening stimulus was present. In the contingent condition, the target that had to be identified always appeared in the same colored circle. Participants could thus intentionally look for this color to identify the target. In the random condition, the target could appear in any colored circle, and was therefore unpredictable. We expected a flat search slope in the contingent condition and a very steep search slope in the random condition.

Method

Participants

Twenty-four students at Ghent University (four men, mean age = 20.4 years, *SD* = 5.0) participated in exchange for course credit. All had normal or corrected-to-normal vision, and reported not to be color-blind. All participants gave their informed consent and were free to terminate the experiment at any time.

Stimulus Material and Apparatus

Experimental stimuli were compound stimuli, always consisting of a line in the centre of a colored circle (diameter of 2.9° radius, and a colored band of 0.5° with a black outline) presented against a silver colored background. There were eight possible colors: blue, turquoise, yellow, green, orange, purple, red and grey. The colors were matched for intensity and luminance (intensity and luminance score of 120 in PAINT program). The color of the centre of the circle was the same as the background color. The lines in the circles were black and extended 1°. They were presented horizontally, vertically, or tilted (22.5° to either side of the horizontal or vertical plane) (adopted from Theeuwes, 1991).

On each trial, the stimulus display consisted of 3, 5, or 7 elements (set size). The elements were equally spaced on an imaginary circle with a diameter of 6.7° visual angle. On each trial, all compound stimuli had different colors, but there was only one target stimulus (a horizontal or vertical line). The remaining compound stimuli contained tilted lines.

Participants had to identify the target (whether the not tilted line segment was horizontal or vertical) using two keys on the keyboard. Responses were made with the index and middle finger of the dominant hand.

Procedure

The experiment was conducted in a dimly-lit, sound-attenuated room. The participants were seated in front of a Dell Optiplex GX520 desktop computer with a 100 Hz 19-inch color monitor. The distance from the screen was approximately 60 cm. The experiment was programmed using the E-Prime software package (Schneider, Eschman, & Zuccolotto, 2002).

Participants were instructed to search for the one line segment that was presented horizontally or vertically among the tilted lines, and to identify its orientation as quickly as possible. Each participant completed two conditions, the order of which was counterbalanced across participants. The experiment started with twenty-three practice trials of the first condition participants were assigned to. Each trial started with a fixation cross at the center of the screen for a duration of 1000 ms. Thereafter, the stimulus display was presented until a response was made. Error feedback was displayed for 500 ms. The inter trial interval was 750 ms. Participants were instructed to focus on the fixation point at the beginning of each trial.

The two experimental conditions consisted of 140 trials each. In the contingent condition, the target always appeared in the same color (e.g. “green”, color counterbalanced across participants). Participants were informed about this contingency at the start of the condition. In the random condition, there was no contingency between the color of the circle and target presence: the target was presented equally often in each of the eight possible colors. There were 36 trials of set size 3, 60 trials of set size 5 and 84 trials of set size 7 in each condition. Total duration of the experiment was approximately 30 minutes.

Results

Data Trimming

Trials with an error or which resulted in outliers were removed from further analyses. Outliers were reactions times that deviated more than 3 standard deviations from the individual mean of correct responses, calculated for every combination of condition and set size separately. There were 4.3% errors and 0.7% outliers. For ease of comparison with the norms of Cohen (1988), we calculated effect sizes and 95% confidence interval for dependent samples using the formula of Morris and DeShon (2002) (see Borenstein, Hedges, Higgins, & Rothstein, 2009). An effect size of 0.20 is considered a small effect, around 0.50 a medium effect and larger than 0.80 a large effect (Cohen,1988).

Reaction Time Data

A 2 (Condition: contingent vs. random) by 3 (Set size: 3, 5, vs. 7) repeated measures analysis of variance (ANOVA) on the reaction time data revealed a significant effect of condition ($F(1, 23) = 263.49$, $p < .001$: overall faster reaction times in the contingent condition than in the random condition), and a significant effect of set size ($F(2, 22) = 114.86$, $p < .001$: a slowing of reaction times with increasing set size). More importantly, there was a significant interaction between condition and set size ($F(2, 22) = 107.28$, $p < .001$): in the random condition, there was a large increase in reaction times with increasing set size while this increase was less pronounced in the contingent condition (Figure 1). We calculated the search slope for each condition separately for each subject by subtracting reaction times on set size 3 from reaction times on set size 7 and dividing the result by the difference in set size, that is, by 4 (Wolfe, 1998; see Theeuwes, 1992 for a similar procedure). The resulting slope represents the increase in reaction time per item presented in the display. The slope in the random condition (*M* = 119 ms, *SD* = 36) was significantly steeper than the slope in the contingent condition (*M* = 10 ms, *SD* = 12; $t(23) = 15.0$, $p < .001$; $d = 3.8$, CI: 2.4 – 5.2). In addition, both slopes were significantly different from zero ($t(23) = 16.0$, $p < .001$ for the random condition and $t(23) = 4.2$, $p < .001$ for the contingent condition). Accuracy analyses indicated no speed accuracy trade-off: there was no difference in accuracy between the consistent and random condition ($t(23) = 1.31$, $p > .20$).

*** Figure 1 ***

Discussion

Experiment 1 revealed that participants were able to search efficiently for the targets when a particular distinctive perceptual feature (color of the circle) was instrumental for successful performance in comparison to when this feature was not predictive of the target. The criterion for pop out is a search slope of no more than 10 ms per item (Wolfe, 1998). The slope in the contingent condition was 10 ms per item. It is important to bear in mind that the constitution of the distractors in this design was different than it is in other studies. Most visual search studies use homogeneous distractors (e.g. Egeth, Jonides & Wall, 1972) whereas this study used a set of heterogeneous distractors. It is known that heterogeneous distractors may lead to less efficient search (Duncan, 1989). It is therefore no surprise that the slope in the contingent condition is above 0 ms/item.

Experiment 2

Experiment 2 was designed to investigate whether threatening stimuli pop out (capture hypothesis) or produce flatter search slopes than neutral stimuli (priority hypothesis). Classical conditioning was used to experimentally create a threatening stimulus (Dawson, Schell, Beers, & Kelly, 1982): one particular color of the circles became a signal (Conditioned Stimulus: CS+) for a painful, aversive electrocutaneous stimulus (Unconditioned Stimulus: US).

We chose the search task variant in which the color of the circles was not predictive of the target (random condition of Experiment 1). This was done for several reasons. First, since this condition leads to a steep search slope, we can test whether there is a slope attenuation by threat. The maximum effect we can expect is a slope of 10 ms/item (contingent condition Experiment 1). Second, the target was presented in the CS+ at chance level, making it possible to determine whether threat truly captures attention, consistent with the visual search tradition (e.g. Yantis & Jonides, 1984; Jonides & Yantis, 1988). Additionally, presenting threat and target at either the same (congruent trials) or different locations (incongruent trials) made it possible to investigate both the facilitative and interfering effects of threatening information. If attention is biased to the threat-related color, we expected fast reaction times on congruent trials compared to baseline trials (where the CS+ is not presented). More specifically, under the capture hypothesis, we expected fast reaction times independent of the number of distractors, meaning pop out. Under the priority hypothesis, we expected less influence of the number of distractors on congruent trials, and thus a flatter search slope than on baseline trials, but no pop out. In addition, under both hypotheses, target detection on incongruent trials should be hampered. Finally, we wanted to explore the putative role of trait anxiety on the capture of attention by threatening information. The meta-analysis of Bar-Haim and colleagues (2007) revealed a moderate attentional bias to threat-related stimuli in anxiety patients and in high-trait anxious individuals, but no attentional bias in low-trait anxious individuals. However, several studies have shown that low-anxious individuals also display an attentional bias to threat if stimuli are highly threatening (Koster et al., 2004; Van Damme, Crombez, Hermans, Koster & Eccleston, 2006). In order to further investigate the role of anxiety, we pre-selected participants in terms of high or low trait-anxiety. Because we used highly threatening stimuli, we expected to find an attentional bias to threat in the whole sample. However, we further expected that the attentional bias would be more pronounced in the high trait anxious individuals than in low trait anxious individuals.

Method

Participants

Participants were recruited via an online screening survey, which was filled out by first year undergraduate psychology students ($N = 538$). The survey contained amongst others a questionnaire assessing trait anxiety (STAI-trait, see below). Eighty students with a STAI-trait score below 35 (low trait-anxious), or above 45 (high trait-anxious) were invited. The median STAI-trait score for Flemish first year psychology students is 40

(Hermans, 1994). The mean STAI-trait score for the total sample in the screening survey was 40.06. Of those who were invited, 48 students participated in the actual study in exchange for course credit. The high trait-anxious (HTA) group consisted of one man and 22 women (N = 23, mean age = 19 yrs, SD = 3.4). In the low trait-anxious group there were seven men and 18 women (N = 25, mean age = 19 yrs, SD = 3.2). All participants had normal or corrected-to-normal vision, and reported not to be color-blind. All participants gave their informed consent, and were free to terminate the experiment at any time. None made use of this option.

Stimulus Material and Apparatus

The stimulus material and apparatus for the visual search task trials were identical to those of Experiment 1. Electrocutaneous stimuli were delivered by a constant current stimulator (DIGITIMER, model DS7A), and administered to the inside of the wrist of the non-dominant forearm by two lubricated Fukuda standard Ag/AgCl electrodes (1 cm diameter). The electrocutaneous stimuli consisted of a series of 38 rectangular pulses (2 ms in duration with an inter pulse interval of 6 ms), and had a total duration of 300 ms. The intensity of the electrocutaneous stimulus was individually determined. In an intensity work up procedure participants indicated the maximum intensity of the electrocutaneous stimulus that they were willing to tolerate. This intensity was used as US throughout the experiment.

Self-Report Instruments

Trait-anxiety was assessed with the Dutch trait version of the State Trait Anxiety Inventory (STAI-trait; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983; Van der

Ploeg, Defares, & Spielberger, 1980), which is a 20-item questionnaire assessing the disposition to feel anxious and distressing (e.g. “I feel calm” , “I am confused”). It is to be rated on a four-point numeric scale (1 = *Not at all* and 4 = *Very often*).

Likert scales were used to assess diverse aspects of the participants’ experience. Participants reported on the intensity of the US, the extent of pain experienced, and the fear of the US using 0-9 Likert scales (anchored by 0 = *Not at all* and 9 = *Extremely*). Another Likert scale assessed the (un)pleasant of the US (anchored by 0 = *Very unpleasant*, 5 = *Neutral* and 10 = *Very pleasant*). There were also Likert scales to assess the US expectation after presentation of the CS+ (anchored by 0 = *Never* and 9 = *Always*), and the experienced fear during the presentation of the CS+ (anchored by 0 = *Not at all* and 9 = *Very much*).

Procedure

Upon arrival, the STAI-trait was completed by the participants. Next, the tolerance level of the electrocutaneous stimulus was determined. Participants were informed that even though most of the electrocutaneous stimuli would be of an intensity at their tolerance level, the intensity could be increased during the experiment. Even though this was not actually done, these instructions have proven effective in increasing the threat value of the electrocutaneous stimulus (Crombez, Eccleston, Baeyens, & Eelen, 1998).

Next, participants practiced the search task during 23 trials. A trial started with a fixation cross in the middle of the screen that was presented for 1000 ms. Thereafter, the search display was presented until a response was made. The color of the circles was not predictive of the target stimulus. Participants were instructed to search for, and identify the target stimulus (whether the line segment was horizontal or vertical) as quickly as possible. Electrocutaneous stimuli were not applied during the practice phase.

During the subsequent acquisition phase, participants were instructed that one color would sometimes be followed by the US. Participants were not informed which color was predictive of the US. Their task was to find out which color it was. There was no search task. Only colored circles without line segments were presented. To facilitate acquisition, this phase started with eight trials of set size 1, followed successively by four trials of set size 3, 5 and 7. The stimuli were presented on the screen for 500 ms, followed by an inter-trial interval of 750 ms. On half of the trials, the color linked to the US (the CS+) was presented. Half of the CS+ trials were followed by the US (partial reinforcement schedule of 50%), which was presented 300 ms after CS+ onset. At the end of the acquisition phase, participants had to report which color was linked to the US. Participants also rated the intensity and the unpleasantness of the US, the extent of pain experienced, and the fear of the US using the Likert scales.

During the experimental phase, we used stimulus displays of set size 3, 5 and 7. Half of the trials contained a horizontal target, the other half a vertical target. This phase consisted of four blocks of 94 trials, with a short break after the second block. Participants were instructed that upon presentation of the CS+, an electrocutaneous stimulus would sometimes follow. There were three types of trials that were presented intermixed with each other. (1) During *congruent trials*, the target was presented in the CS+; (2) During *incongruent trials*, the CS+ was present but the target was depicted in another colored circle; (3) During *baseline trials*, a target, but no CS+ was present. An example of the different trial types can be found in Figure 2. The CS+ was no longer reinforced at a rate of 50% but we installed the following procedural aspects to make sure that the threat-related color (CS+) remained threatening and predictive of the US. First, only half of the trials contained the CS+ in order to avoid habituation and extinction of fear (for a review, see Hofmann, 2008). Second, during each block, four trials in which the CS+ was followed by the US were added to avoid extinction (Mackintosh, 1974). Finally, to make sure that participants could not strategically use the CS+ to localize the target, we used the 1/n procedure (where n is set size; Jonides & Yantis, 1988) so that for each set size, the CS+ was not predictive of the target. This means that for set size 3, one out of three CS+ trials was a congruent trial. For set size 5, one out of five CS+ trials was a congruent trial. For set size 7, one out of seven trials was a congruent trial. All trial types were mixed within blocks. A detailed account of the distribution of trials can be found in Table 1.

*** Figure 2 ***

After Blocks two and four, participants were requested to report the intensity and the unpleasantness of the US, the extent of pain experienced, and the fear of the US. After Block four, they also reported to what extent the US was expected after presentation of the CS+, and the experienced fear during the presentation of the CS+.

*** Table 1 ***

Results

Data Trimming

There was one low trait anxious (LTA) participant whose STAI-trait score at the beginning of the experiment was higher than 40 and two high trait anxious (HTA) participants whose STAI-trait scores at the beginning of the experiment were lower than 40. The data of these participants were not included in the further analyses. This resulted in a final sample of 24 LTA participants (seven men, mean age = 19.05, *SD* = 2.5) and 21 HTA participants (one man, mean age = 19.08, *SD* = 3.2).

After the acquisition phase, all participants were able to correctly identify the CS+, and hence no participants were excluded. Trials on which an US was presented were not taken into account for analyses. Also trials with incorrect responses (6.6%) and outliers (2.6%) were removed. Outliers were defined as reaction times that deviated more than three standard deviations from the individual mean of correct responses, calculated for every cell in the design. We calculated Cohen's *d* and its 95% confidence interval (CI) for relevant terms.

Questionnaires and Self Reports

The HTA and LTA group differed significantly in their STAI-trait scores at the start of the experiment (HTA group: $M = 53.1$, $SD = 9.8$; LTA group: $M = 29.6$, $SD = 4.6$; $t(43) = -10.52$, $p < .001$). The LTA group selected a significantly higher US intensity ($M = 3.07$ mA, $SD = 2.2$) than the LTA group ($M = 1.97$ mA, $SD = 1.3$; $t(43) = 2.09$, $p < .05$). Self-report data were averaged across blocks. The only difference between the non-aggregated ratings was that after the second block, high anxious participants rated the US as more frightening (M = 6.3, SD = 1.9) than the low anxious participants (M = 4.9, SD = 2.6; t(43) = 2.24, p < .05). Participants rated the US as moderately frightening (*M* =

5.6, *SD* = 2.0), intense (*M* = 6.0, *SD* = 1.5), painful (*M* = 5.0, *SD* = 2.1) and unpleasant (*M* = 3.6, *SD* = 2.0). Participants had a realistic expectation of the occurrence of the US (*M* = 3.9, *SD* = 2.2), and they were slightly anxious when the CS+ was presented (*M* = 3.6, *SD* = 2.6). The US ratings did not differ between the HTA and LTA groups (all $p >$ .1).

Reaction Time Data

A 2 (Group: LTA, HTA) x 3 (Trial type: congruent, incongruent, baseline) x 3 (Set size: 3, 5, 7) repeated measures ANOVA was performed on the reaction time data. The latter two variables were within-subject. There was a significant main effect of Group ($F(1, 42) = 4.48$, $p < .05$; $d = .56$, CI: -0.03 – 1.16), indicating that the HTA group generally reacted faster (*M* = 1048 ms, *SD* = 121) than the LTA group (*M* = 1132 ms, *SD* = 166). There was also a main effect of Trial type ($F(2, 41) = 41.52$, $p < .001$). Comparison analyses revealed that reaction times on congruent trials (*M* = 912 ms, *SD* = 142) were shorter than those on baseline trials (*M* = 1076 ms, *SD* = 159; $t(44) = 10.29$, $p < .001$; $d = 1.08$; CI: 0.82 – 1.34) which we call the facilitation effect. Reaction times on incongruent trials (*M* = 1125 ms, *SD* = 161) were longer than those on baseline trials ($t(44) = 6.79$, $p < .001$; $d = 0.31$, CI: 0.21 – 0.40), which we call the interference effect. Therefore reaction times on congruent trials were shorter than those on incongruent trials ($t(44) = 11.48$, $p < .001$, $d = 1.40$, CI : 1.06 – 1.73). Also the main effect of Set size was significant ($F(2, 41) = 533.79$, $p < .001$), indicating that reaction times increased with increasing set size (*M* set size 3 = 810 ms, *SD* = 105; *M* set size 5 = 1022 ms, *SD* = 152; *M* set size 7 = 1237 ms, *SD* = 179).

Of particular relevance is the significant interaction between Trial type and Set size ($F(4, 39) = 2.90$, $p < .05$). A comparison of the slopes of the three trial types revealed that the slope of the congruent trials (90 ms/item, $SD = 47$) was flatter than the slope of the baseline trials (105 ms/item, $SD = 31$) ($t(44) = -2.33$, $p < .05$; $d = 0.38$, CI: -.05 - .71) and flatter than the slope of the incongruent trials (106 ms/item, $SD = 31$) ($t(44) = -1.98$, $p = .05$; $d = .41$, CI: -.01 - .83). This means that the effect of set size was less pronounced for the congruent trials than for the baseline and incongruent trials. The latter two had equal slopes ($t < 1$; $d = 0.02$, CI: -.30 - .34). The mean reaction times for this interaction are presented in Figure 3.

*** Figure 3 ***

The Group x Trial type interaction ($F(2, 41) = 2.50$, $p > .1$), nor the Group x Set size interaction ($F(2, 41) = 1.77$, $p > .1$) nor the Group x Trial type x Set size interaction ($F(4, 39) = 1.37$, $p > .25$) were significant. For further consideration, the HTA group responded faster than the LTA group on congruent trials ($F(1, 44) = 9.21$, $p < .005$; $d = 0.91$, CI: 0.29 – 1.52) and baseline trials ($F(1, 44) = 4.86$, $p < .05$; $d = 0.66$, CI: 0.06 – 1.26), but not on incongruent trials ($F(1, 44) = 1.23$, $p > .1$; $d = 0.33$, CI: -0.26 – 0.92). As a consequence, the HTA group showed a larger interference effect ($M = 75$ ms, $SD = 46$) than the LTA group ($M = 27$ ms, $SD = 40$; $t(43) = 3.68$, $p < .005$; $d = 1.10$, CI: 0.47 – 1.73) but not a larger facilitation effect ((M LTA = 157 ms, $SD = 120$, M HTA = 174 ms, $SD = 92$; $t < 1$). Note that the search slope on baseline trials in Experiment 1 (119 ms per item, SD = 36) was not significantly different from the slope on baseline trials in Experiment 2 ($t(67) = 1.66$, $p > .1$).

Discussion

Experiment 2 was designed to investigate whether threatening information captures or prioritizes attention. Self-reports indicated that we were successful in creating a threat-related signal: the threat-related color (CS+) was experienced as threatening and predictive of the painful US.

The results revealed that threatening information does not capture attention because on congruent trials, there was no 10 ms pop out slope (as established in Experiment 1). In other words, the results do not support the capture hypothesis. It is however clear that threatening information biases attention by affecting the efficiency of the search process. We found faster reaction times when the threat-related color and the target were presented at the same location (congruent trials) than when they were presented at different locations (incongruent trials) or when the threat-related color was not present (baseline trials). The reaction times on congruent trials were also less influenced by the number of distractors as predicted by the priority hypothesis. Previous studies face the potential problem that effects of threat may have resulted from participants adopting a search strategy based on a particular perceptual feature of the threatening stimulus. There are several reasons why this problem does not apply here. First, the threat-related color was not predictive of the target. Because of this, adopting the strategy to look for a particular color in order to find the target was not instrumental. Second, because the color of the threat-related stimulus was counterbalanced across participants, it is unlikely that the effect was caused by the saliency of a particular color. The results of our study differ from the results of a similar study (Batty et al., 2005) that did not find a flatter search slope for a threat-related than for a neutral target. However, they had a different research question, namely whether threat as an affective feature (independent of perceptual features) can be detected pre-attentively. Therefore, they used complex visual stimuli (conjunction of perceptual features) that cannot be detected pre-attentively (Treisman & Gelade, 1980). The crucial test was whether a target that was associated with threat through evaluative conditioning would nevertheless pop out among the distractors because the threat value of the target (an affective feature) can be detected pre-attentively. The results of their study did not support this hypothesis. In the present study, we wanted to investigate whether perceptual features associated with threat can capture or prioritize attention. Thus, in our study, the threat-related feature was a simple perceptual feature (color), which can pre-attentively bias attention (LeDoux, 1998).

A notable null-result in the current study is that we failed to observe differences between high- and low-anxious participants although we had expected such effect (see Bar-Haim et al., 2007). A reason may be that our signal for the electrocutaneous stimulus was equally threatening for both high- and low-anxious participants (indeed, there were no differences in the ratings) because the intensity of the electrocutaneous stimulus was at tolerance level for both groups. It is plausible that individual differences in attention will only emerge with stimuli of lower but fixed intensity (see Crombez et al., 1998; Mogg & Bradley, 1998). We expect that presenting the US at a lower, fixed intensity would reveal differences between high and low trait anxious participants. More specifically, we expect that high trait anxious participants would show a larger facilitation and interference effect (see also Koster, Crombez, Verschuere, Van Damme & Wiersema, 2006) and more prioritization of the CS+ than low trait anxious participants.

General Discussion

Previous research suggests that threatening information captures attention more rapidly than neutral information (e.g. Öhman, Flykt et al., 2001; White, 1995). However, in most studies threat stimuli differ perceptually from neutral stimuli and are instrumental to perform the task. Therefore, the main objective of this paper was to investigate whether threat itself can capture or prioritize attention. In this study, one particular color (CS+) became predictive of an aversive electrocutaneous stimulus via a procedure of classical conditioning. The threatening stimulus (CS+) was not predictive of the target, making an intentional search for the threatening stimulus in order to identify the target not instrumental. This also allowed us to investigate both facilitation (the target is presented within the CS+; congruent trials) and interference (the target is not in the CS+; incongruent trials) by the threatening stimulus. The results can be readily summarized. First, we found an attentional bias to threatening stimuli that was characterized by a facilitation effect (large effect size: $d = 1.08$) and an interference effect (small effect size: $d = 0.31$). Second, we found an attenuation of the slope on congruent trials. Although this slope markedly increased as set size increased, it was less affected by set size than the slope on baseline trials. This supports the priority hypothesis, which posits that threatening information does not capture but prioritizes attention. Third, we did not observe differences in attentional bias to the threatening stimulus between high and low trait anxious participants.

Attentional bias to threat has already been reliably demonstrated under a variety of experimental paradigms, conditions, and (sub-)clinical populations, albeit with a moderate effect size (Bar-Haim et al., 2007; *d* = 0.45; CI: 0.40 - 0.49). In our study, the attentional bias to threatening information (reaction times on incongruent trials minus reaction times on congruent trials) is, in comparison, remarkably large in its effect size (*d* = 1.40, CI: 1.06 – 1.73). There may be several reasons for this. First, previous studies investigating attentional bias were using complex stimuli (e.g. words, faces and pictures), whereas we used simple visual stimuli (e.g. colors). It is possible that especially these simple features can modify the allocation of attention (LeDoux, 1998; Öhman & Mineka, 2001), making it possible to detect attentional engagement with threat. Second, using a classical conditioning procedure, we created a situation that was threatening for all participants, and involved an actual aversive stimulus. Third, it may be that the selection of threatening information especially emerges within a context of multiple, competing stimuli (Crombez et al., 2005). Indeed, previous studies using simple visual stimuli and a similar classical conditioning procedure (Van Damme et al., 2004; Van Damme, Crombez, Eccleston & Koster, 2006) only revealed an effect size of *d* = 0.60, CI: 0.28 – 0.91. A remarkable difference is that in these studies the spatial cueing paradigm (in which only one cue is present) was used, whereas in our search paradigm the number of cues/distractors was larger (set size 3, 5 or 7). Indeed, despite some notable procedural differences, several experimental paradigms can be considered variants of our visual search paradigm. The spatial cueing task resembles set size 1, and the dot-probe paradigm resembles set size 2. Thus, our search paradigm may shed light on the small attentional bias effect sizes found in studies using these other paradigms (see Cisler, Bacon & Williams, 2009).

Of particular importance to this study was to test whether signals of threat capture or prioritize information. Our results are clear in showing that there is no evidence for an attentional capture by threat. The slope difference between congruent and baseline trials is however sufficient to conclude that a pre-attentive bias for threat influences visual search processes (Frischen et al., 2008). This supports the priority hypothesis. This is an important result because the effect can only be caused by the threat value of the color stimulus. It cannot be caused by some notable perceptual feature of the target or distractors (the lines) because these were the same in all conditions. The attenuated slope on congruent trials is in line with results from Gerritsen et al. (2008). They set up a series of visual search tasks to investigate whether negative emotional faces can guide attention. In an attempt to rule out possible influences of the physical properties of the faces, they used the same neutral faces across observers, but used a conditioning procedure to attach different emotional meanings to the faces. However, it must be noted that this procedure does not rule out he possibility that participants quickly learn to select one particular feature of each face, and subsequently intentionally use this feature to guide search, instead of the face's emotional meaning. Their results show more efficient search (i.e. flatter search slopes) for hostile than for peaceful faces among neutral face distractors (Gerritsen et al., 2008).

If threat leads to prioritization of attention, how would such prioritization take place? A possible explanation for the facilitation effect can be found when taking into account the combination of factors that influence the responses on different trial types. In general, the most important stimulus for the subjects to attend to is the target, because identification of the target is necessary to perform the task adequately. In addition, even though it is not relevant for the target detection task, the threat-related color (CS+) can be more important than the other colors because it does signal an aversive electrocutaneous stimulus. This ‘importance’ can be formulated in terms of activation values in the Guided Search Model (Cave & Wolfe, 1990) or pertinence values or weights in the Theory of Visual Attention (Bundesen, 1990). On baseline trials, only the target stimulus is present in the display which leads to the typical set size effect (slower reaction times with larger set size). On congruent trials, both the target and the threat-related color are presented at the same location as one combined stimulus. Thus, presenting both stimuli that are of importance together at the same location will lead to shorter reaction times than on baseline trials.

The interference effect in other studies is most often explained by a delayed disengagement from the threatening stimulus (Fox et al., 2001; Yiend & Mathews, 2001). This is also a plausible explanation in our study, since the slope of the incongruent trials is equal to the slope of the baseline trials. This can be explained in the same way as the facilitation effect. The higher importance of the CS+ color compared to the other colors increases the chance that participants will start scanning the display for the target at the location of the threat-related color. On incongruent trials, this means that there is a fast rejection of the distractor line segment presented in the CS+. To continue the search for the target, participants now have to disengage their attention from the CS+. However, a very robust phenomenon in the literature concerning attentional bias to threat is (especially in high-anxious individuals) a difficulty disengaging from threatening information (e.g. Fox et al., 2001; Yiend & Mathews, 2001; Koster, Crombez, Verschuere et al., 2004; Koster et al., 2006). This difficulty disengaging from the CS+ in order to find the target can thus lead to slower reaction times on the incongruent trials than on baseline trials. In Experiment 2, HTA participants showed a larger interference effect than LTA participants. Consistent with previous literature, we assume that this effect arose because high anxious people have more difficulty disengaging attention from threatening information than low anxious people.

Although our results clearly indicate that threat does not capture attention, it remains important to explore conditions that may allow for such capture. We provide some possibilities. First, attentional capture to threat might occur when individuals use a broad instead of a narrow attentional window. Our paradigm might have led participants to set a small "attentional window" in order to sequentially check parts of the search display for the target (Theeuwes, 2004). Attentional capture by salient elements is then only possible within this attentional window, but not outside the window. Further research investigating attentional capture by threat could manipulate the attentional window (see Belopolsky, Zwaan, Theeuwes & Kramer, 2007).

Second, individuals may phenomenologically experience an attentional capture by threat, although there is no real capture present. For example, a patient with spider phobia may more rapidly detect spiders than individuals without such fear, and experience it as an attentional capture. However, this type of attentional capture may be dependent upon the attentional scanning of particular places with a high probability for spiders (e.g. dark corners). Our paradigm may be easily adapted to investigate whether attentional capture emerges when the signal of threat is spatially predictable.

Third, an attentional capture by threat may emerge when participants have the ability to escape or avoid the aversive event (Van Damme, Legrain, Vogt, & Crombez, 2010). In the majority of studies investigating the threat bias, such a reaction to threat is not possible. Also in our paradigm, the classical conditioning procedure by definition does not allow instrumental responses of escape or avoidance. We may expect that implementing such actions in our paradigm, would automatically increase the goal-relevance of signals of threat and its potential to capture attention.

There are some limitations to this study. First, although the intensity of the unconditioned stimulus (US) was set at tolerance level, ratings of the aversiveness of this stimulus were moderate. It remains possible that with more aversive stimuli, a flatter slope for congruent trials would be observed. Second, our results may not generalize to clinical samples with trait anxiety because in this study we only pre-selected sub-clinically high and low trait-anxious students. Third, search latencies in Experiment 2 were overall slow. This could possibly have led to ceiling effects, resulting in an underestimation of the interference effect. Fourth, it is possible that presenting the target in the threat-related stimulus on congruent trials in Experiment 2 may have caused a Stroop-like effect (response slowing because of the presence of threat; Mogg et al., 2008).

In conclusion, we propose a promising new paradigm to investigate attentional bias to threat, in which we showed that the threat value of a task-irrelevant conditioned stimulus leads to prioritization of attention in a visual search task.

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Table 1

Distribution of Trials in each of the Blocks in Experiment 2.

Trial type	Set size 3	Set size 5	Set size 7
Congruent	3	3	3
Incongruent	6	12	18
Baseline	9	15	21

Figure Captions

Figure 1: Mean reaction time and standard errors for each set size in the Random and Contingent condition of Experiment 1.

Figure 2: Examples of the different stimulus displays (not to scale). The spotted circle represents the CS+. Panel A: Baseline trial of set size 3 with horizontal target. Panel B: Congruent trial of set size 5 with horizontal target. Panel C: Incongruent trial of set size 7 with vertical target.

Figure 3: Mean reaction times and standard errors for each set size and trial type in Experiment 2.

Figure 1

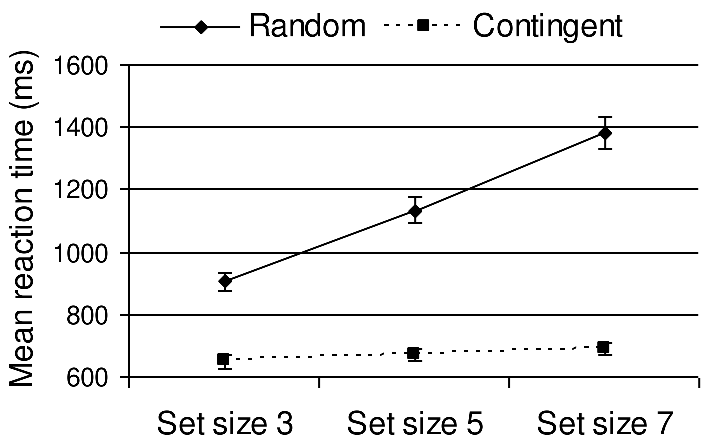

Random
Contingent
Mean reaction time (ms)
1600
1400
1200
1000
800
600
Set size 3
Set size 5
Set size 7

Figure 2

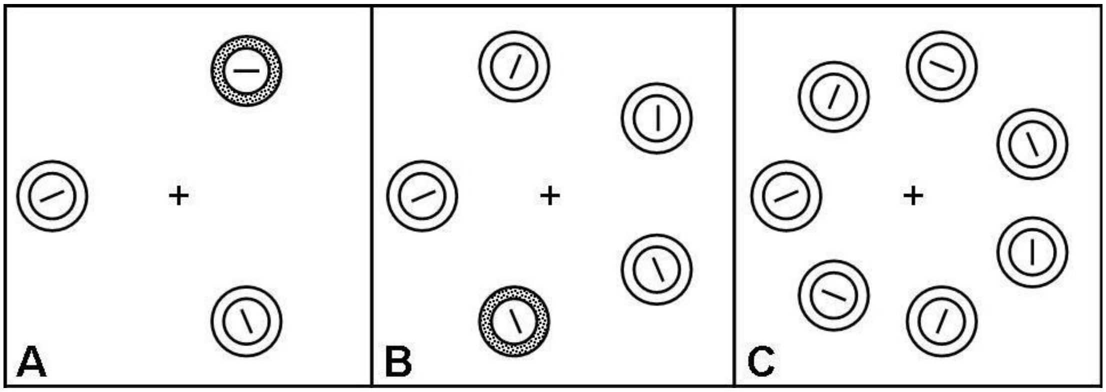
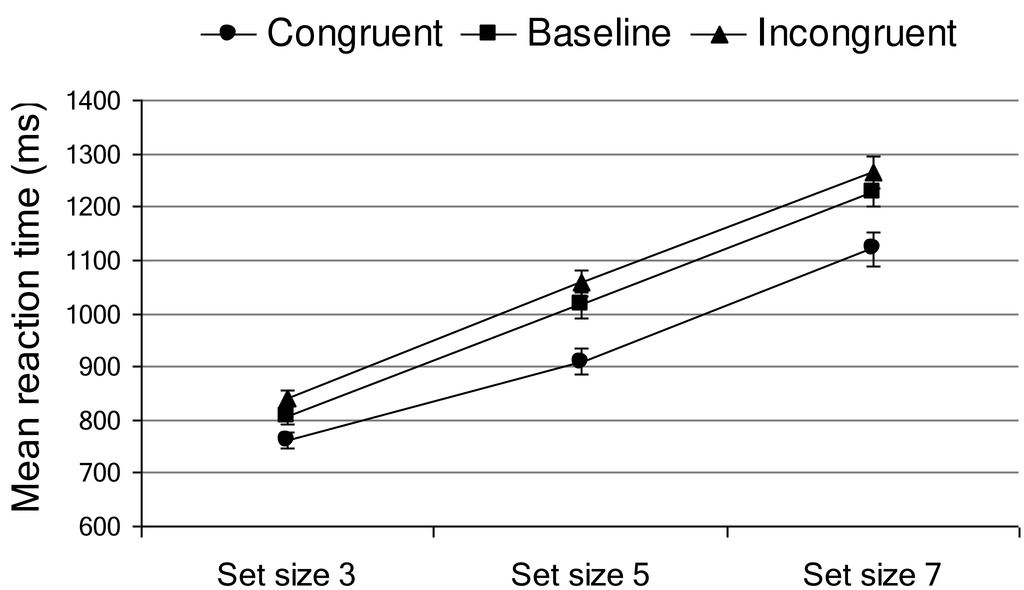


Figure 3


Congruent
Baseline
Incongruent
Mean reaction time (ms)
1400
1300
1200
1100
1000
900
800
700
600
Set size 3
Set size 5
Set size 7

Supplementary material for online publication

Detailed table of Figure 2

Mean reaction time (M) and standard deviation (SD) for each set size in the Random and Contingent condition of Experiment 1

		Set size 1	Set size 3	Set size 5	Set size 7
Random	*M*	584	891	1191	1504
	SD	69	103	169	272
Contingent	*M*	537	601	628	660
	SD	57	61	64	70

Detailed table of Figure 3

Mean reaction times (M) and standard deviations (SD) for each set size and trial type in Experiment 2.

		Set size 3	Set size 5	Set size 7
Congruent	*M*	765	914	1128
	SD	107	169	219
Baseline	*M*	810	1020	1232
	SD	115	167	189
Incongruent	*M*	843	1060	1268
	SD	111	158	196