Attentional Bias to Threat: A Perceptual Accuracy Approach

Article *in* Emotion · January 2009

Impact Factor: 3.88 · DOI: 10.1037/a0014149 · Source: PubMed

3 authors:


Stefaan Van Damme
Ghent University
118 PUBLICATIONS **3,760** CITATIONS
SEE PROFILE


Geert Crombez
Ghent University
417 PUBLICATIONS **16,768** CITATIONS
SEE PROFILE


Lies Notebaert
University of Western Australia
18 PUBLICATIONS **228** CITATIONS
SEE PROFILE

Emotion
2008, Vol. 8, No. 6, 820–827

1528-3542/08/$12.00 DOI: 10.1037/a0014149

Attentional Bias to Threat: A Perceptual Accuracy Approach

Stefaan Van Damme, Geert Crombez, and Lies Notebaert
Ghent University

To investigate attentional bias to threatening information, the authors propose a new version of the spatial cueing paradigm in which the focus is on perceptual accuracy instead of response speed. In two experiments, healthy volunteers made unspeeded discriminations between three visual targets presented left or right. Each target was preceded by a visual cue (colored rectangle) at either the same (valid) or opposite (invalid) location. By means of differential classical conditioning with aversive white noise, a threat cue and a control cue were created. Analyses of error rates showed that cueing effects (lower proportion of errors in valid trials relative to invalid trials) were more pronounced in threat trials than in neutral trials. This threat-related bias was particularly because of threat cues reducing accuracy in invalid trials, indicating difficulty disengaging attention from threatening information. Engagement of attention was not affected by threat, as threat cues did not facilitate the processing of targets in valid trials. The findings are discussed in light of the strengths and limitations of spatial cueing tasks.

Keywords: attentional bias, threat, perceptual accuracy, classical conditioning

Coherent and goal-directed behavior in a complex and unpredictable environment requires efficient selection of information. An important function of our attention system is to focus on information that is relevant for dealing with important demands such as threat (Eccleston & Crombez, 1999; Lang, Bradley, & Cuthbert, 1990). Consequently, preferential processing of threatening information has been argued to facilitate the initiation of adaptive behavior (Vuilleumier, 2005). However, when attention is excessively biased toward relatively mild threats, this mechanism might become maladaptive. Indeed, biases in information processing are believed to play a role in the development and/or maintenance of clinical anxiety states (Eysenck, 1997; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Williams, Watts, MacLeod, & Mathews, 1997).

The idea that attention is biased to threatening information is well-documented (see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van Yzerdoorn, 2007). One mechanism by which priority processing of threatening information is believed to occur is the allocation of attention to its location in space (Crawford & Cacioppo, 2002). Consequently, it comes as no surprise that a substantial part of the literature has focused upon biases in spatial attention. This is typically investigated using experimental paradigms such as the dot-probe task (MacLeod, Mathews, & Tata, 1986). In this paradigm, a threat stimulus and a neutral stimulus are simultaneously presented on each trial, after which a small probe appears at the location of one of these stimuli. Participants are required to respond as quickly as possible to the probe, with faster responses to probes at the threat location relative to the neutral location being indicative of attentional bias to threat (for some recent examples see Cooper & Langton, 2006; Koster, Verschuere, Crombez, & Van Damme, 2005b; Salemink, van den Hout, & Kindt, 2007). The interpretation of results obtained from the dot-probe paradigm is however limited: it is not clear whether effects are because of faster engagement to threat stimuli, delayed disengagement from threat stimuli, or a combination of both. The differentiation between these attention components is of importance in understanding its role in clinical anxiety, and in designing intervention strategies (Bögels & Mansell, 2004; Koster, Crombez, Verschuere, Van Damme, & Wiersema, 2006).

To disentangle different attention components, researchers have used an emotional modification of the spatial cueing paradigm (Posner, 1980; Stormark, Nordby, & Hugdahl, 1995). In this paradigm a threat or neutral cue is shown and then followed by a target which is presented at the same (valid trial) or the opposite (invalid trial) location. Participants are required to respond as quickly as possible to the probe, with typically faster responses on valid trials compared to invalid trials when cue-target intervals are short (validity effect). A larger validity effect for threat cues relative to neutral cues is indicative of an attentional bias to threat. With this methodology, effects can be decomposed into facilitated engagement to threat cues (faster responses to valid threat trials relative to valid neutral trials) and delayed disengagement from threat cues (slower responses to invalid threat trials relative to invalid neutral trials). Although delayed disengagement has been claimed to be the central component of attentional bias to threat (Fox, Russo, Bowles, & Dutton, 2001; Yiend & Mathews, 2001), it must be noted that a number of studies also found facilitated engagement by threat (e.g., Fox, Mathews, Calder, & Yiend, 2007; Koster, Crombez, Van Damme, Verschuere, & De Houwer, 2005a;

Stefaan Van Damme, Geert Crombez, and Lies Notebaert, Department of Experimental-Clinical and Health Psychology, Ghent University.

Stefaan Van Damme is a postdoctoral fellow of the Fund for Scientific Research Flanders (FWO). We thank Roel Custers for his contribution in the data collection of the first experiment. The authors are also grateful to Elaine Fox and two anonymous reviewers for their useful and stimulating comments and suggestions.

Correspondence concerning this article should be addressed to Stefaan Van Damme, Department of Experimental-Clinical and Health Psychology, Ghent University, Henri Dunantlaan 2, 9000 Ghent, Belgium. E-mail: stefaan.vandamme@ugent.be

Mathews, Fox, Yiend, & Calder, 2003; Van Damme, Crombez, Hermans, Koster, & Eccleston, 2006).

Typical for studies using the spatial cueing paradigm to examine biased attention to threat is that the conclusions are based upon reaction time data, obtained from either speeded detection or speeded discrimination tasks. However, this might be problematic in two ways. First, attentional bias effects have been shown to be short-lived (Calvo & Avero, 2005; Koster, Crombez, Verschuere, Vanvolsem, & De Houwer, 2007; Mogg, Bradley, Miles, & Dixon, 2004). As a consequence, reaction times may not be well suited for detecting biases in populations characterized by overall slow reaction speed or psychomotor slowing resulting from aging, depression, chronic illness, or medication use. Overall, slower reaction times and increased reaction time variability might blur the often subtle effects of threat upon attention. Second, it has been argued that reaction times in speeded spatial cueing tasks do not necessarily reflect effects on the perceptual stage of processing (Prinzmetal, McCool, & Park, 2005; Santangelo & Spence, 2008).

To clarify the latter problem, we refer to a series of spatial cueing experiments reported by Prinzmetal et al. (2005). They showed that the perceptual representation of targets (measured by accuracy in identification) is only affected by cues that are spatially informative and when participants are instructed that accuracy but not response speed matters. The mechanism underlying cueing effects on perceptual accuracy is what Prinzmetal et al. call "channel enhancement," which means that the visual system gathers more information from attended than from unattended locations. In contrast, when exogenous cues only affect reaction times to targets without actually affecting their perceptual representation, this is the effect of "channel selection." This means that the cue affects a decision process, that is, which location contains the target rather than a perceptual process.

In attentional bias studies, increased spatial cueing effects in threat trials are assumed to reflect increased attention to the location of threat cues, as a result of which more information is available in the cued location. However, this assumption is only correct when also accuracy in target identification would be affected. Until now, however, attentional bias studies using the spatial cueing task have only found effects of threatening cues on reaction times but not on accuracy. Such pattern of results might simply indicate effects of threat cues on the response stage of processing, that is, faster selection of a target location before the identification of the target. This response stage explanation is even more likely for studies in which the task is to localize the target using left-right responses (e.g., Fox et al., 2001; Koster et al., 2005a; Van Damme et al., 2006). Spatial cueing effects then can be alternatively explained in terms of stimulus-response mapping (Kornblum, Hasbroucq, & Osman, 1990; Lu & Proctor, 1995), which in turn can be modulated by the threat value of stimuli (Schrooten & Smulders, 2007). Note that this particular problem does not apply to studies in which responses to targets were independent of their location (Fox et al., 2001, Experiment 4; Fox, Russo, & Dutton, 2002, Experiment 1; Yiend & Mathews, 2001), and that in these studies similar results were found.

To overcome problems associated with the use of reaction times, the present study utilizes a spatial cueing paradigm built around perceptual accuracy in two experiments. To make sure that we measure effects at the perceptual level of processing, we followed two recommendations proposed by Prinzmetal et al. (2005): (1) cues must be spatially informative, and (2) participants must be explicitly instructed that accuracy but not response speed matters. In this perceptual accuracy paradigm, one of three possible visual target stimuli was presented left or right, and participants were instructed to determine which target they had seen. Each target was preceded by a simple visual cue, which was made threatening or neutral by means of differential classical conditioning. In the same line as attentional bias studies built around reaction times, we expected that accuracy would be better in valid trials relative to invalid trials, and that this validity effect would be more pronounced for threat cues compared to neutral cues. More particularly, we hypothesized that (1) accuracy in valid trials would be higher for threat cues compared to neutral cues, reflecting facilitated engagement by threat, and (2) accuracy in invalid trials would be lower for threat cues compared to neutral cues, because of difficult disengagement from threat.

Experiment 1

In this experiment participants were asked to differentiate between three targets (arrow pointing left, up, or right) presented left or right. Each arrow was preceded by a cue that was threatening or neutral. Because this is the first study using this new approach, we maximized the effects of threat upon attention by using stimuli that were threatening for all participants. More specifically, we used simple cues (colored squares) that were made threatening or neutral by implementing a differential fear-conditioning paradigm within the task. The threat cue (CS+) was sometimes followed by a highly aversive white noise (unconditioned stimulus; US), whereas the control cue (CS−) was never followed by this US. Fear-conditioned cues have been shown to successfully capture spatial attention in previous studies (Armony & Dolan, 2002; Koster, Crombez, Van Damme, Verschuere, & De Houwer, 2004; Van Damme, Lorenz, Eccleston, Koster, De Clercq, & Crombez, 2004; Stormark, Hugdahl, & Posner, 1999). We hypothesized that accuracy would be higher in valid trials relative to invalid trials, and that this validity effect would be stronger in CS+ trials compared to CS− trials.

Method

Participants

Twenty-one undergraduate psychology students (1 male and 20 females; mean age = 18.42, *SD* = 1.12) from Ghent University participated to fulfill course requirements. The study protocol was approved by the ethical committee of the Faculty of Psychology and Educational Sciences at Ghent University. All participants gave their informed consent and were free to terminate the experiment at any time.

Self-Reports

Trait anxiety in our sample was assessed by the trait version of the State and Trait Anxiety Inventory (STAI-T; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). This instrument can be used in both clinical and nonclinical populations. This questionnaire consist of 20 statements (e.g., I'm feeling nervous) on which participants have to assess themselves, using a 4-point scale (1 = not at all to 4 = all the time). The Dutch version of the STAI-T has been shown to be reliable and valid (Van der Ploeg, Defares, & Spielberger, 1980).

As a manipulation check, participants rated to what extent they found the UCS unpleasant and threatening using 11-point numerical graphical rating scales (anchored 0 = not at all and 10 = very strongly). Furthermore, participants reported to what extent they expected/feared the US after the CS+ and after the CS− at the end of the acquisition phase using 11-point numerical graphical rating scales (anchored 0 = not at all and 10 = very strongly).

Behavioral Task

The spatial cueing task was programmed and presented by the INQUISIT Millisecond software package, which measures response times with millisecond accuracy (De Clercq, Crombez, Roeyers, & Buysse, 2003). The sequence of stimuli is illustrated in Figure 1. All stimuli were presented against a black background. Each trial started with a white fixation cross which was presented in the middle of the screen. After a variable amount of time (one of eight times between 1,500 and 3,500 milliseconds in 250 milliseconds intervals), a spatial cue (square colored in blue or yellow; 1.4 × 1.4 cm) was presented for a duration of 175 milliseconds on one side of the screen (9 cm between the center of the cue and the fixation cross). A target stimulus followed the cue at offset, and consisted of a white arrow (within a black square of 5.5 × 5.5 cm) pointing left, up, or right, which was presented on either the same side or the opposite side of the screen (again 9 cm from fixation). After 150 milliseconds, the target was masked with black and white cross-hatching, and the mask remained on the screen until a response was made. Cue location correctly predicted target location on two thirds of the trials (valid trials). On the remaining trials, cue location incorrectly predicted target location (invalid trials). Participants were instructed to indicate the direction of the arrow (left, up, or right) by pressing the corresponding key (4, 8, 6) on a keyboard. They were instructed to do this as accurately as possible, and they were encouraged to take their time as response speed didn't matter.

The US consisted of a 1,000 milliseconds burst of white noise delivered through a Sony headphone at an intensity of 90 dB. Cues were differentially conditioned by their color. In one third of the presentations, the conditioned cue (CS+) was followed by the US 150 milliseconds after offset. The other cue (CS−) was never followed by the US. The colors of the CS+ and CS− were counterbalanced. The CS+ and CS− were presented equally often, in a fixed random order with a maximum of three consecutive presentations of the same cue.

Procedure

Participants were tested individually in a sound-attenuated room. First, they were informed that an aversive noise stimulus would be used during the experiment, after which participants gave their informed consent. No individuals refused or withdrew their participation. Next, they completed the STAI-T. After this, the participants were seated at 60 cm viewing distance from the computer screen to perform the task. All instructions were presented on the screen. This was followed by a practice phase, in which participants performed 20 trials of the spatial cueing task (without US presentations). Next, there was a baseline phase consisting of 120 trials without US presentations. In the acquisition phase, consisting of 144 trials, one third of the CS+ presentations were followed by an US (in all trial types). After the acquisition phase, participants completed the US rating scales, and the expectancy and fear ratings.

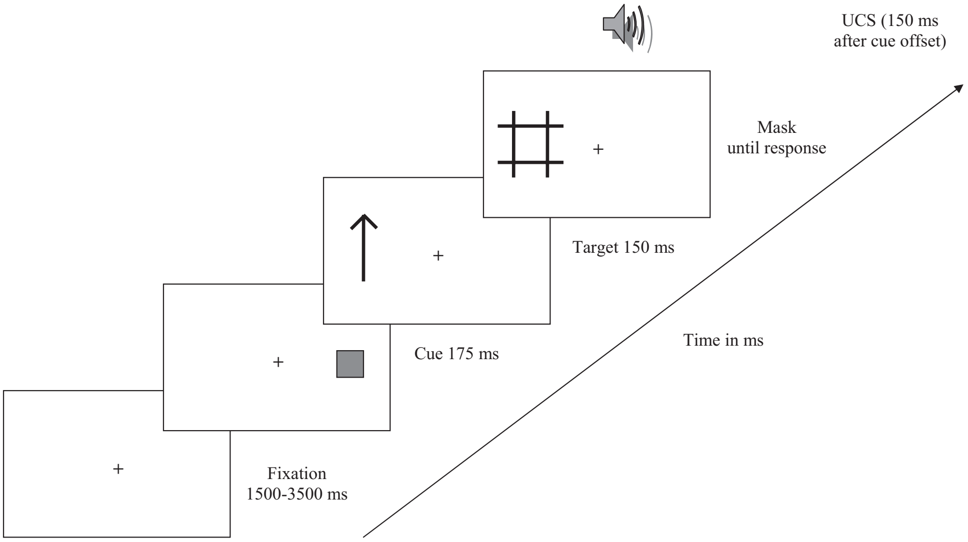

Figure 1. Schematic illustration of sequence of stimuli in an invalid trial. Each trial starts with a fixation cross in the middle of the screen. After a variable amount of time (between 1500 and 3500 milliseconds), a cue (colored square) is presented for a duration of 175 milliseconds on one side of the screen. A target stimulus (arrow) follows the cue at offset on the opposite side of the screen. After 50 milliseconds (spatial cueing paradigm) or 150 milliseconds (antisaccade task), the target is masked until a response is made. In one third of the CS+ trials, an aversive white noise (90 dB; 1000 milliseconds) is presented 150 milliseconds after cue offset.

Data Reduction and Statistical Analyses

All analyses were performed upon the number of errors (no reaction times were registered). Inspection of the data showed that the error rates of two participants were more than 2 *SD*s above the mean error proportion of the sample, and that one of these participants responded at chance level. Data from both participants were considered outliers and excluded from further analyses. Trials with US presentations were omitted from the analyses, to prevent interpretation of the effects in terms of interference by the noise stimulus itself. A 2 × 2 repeated measures ANOVA was performed upon the percentage of correct responses in the acquisition block of the 19 remaining participants, with cue validity (valid, invalid) and signal (CS+, CS−) as within-subjects variables. As a control, a similar ANOVA was performed upon the percentage of correct responses in the baseline block. Note that for the factor signal the future CS+ and CS− were used, as there was no differential conditioning during the baseline block. Greenhouse-Geisser corrections (with corrected degrees of freedom) were reported if the sphericity assumption was violated (Mauchly's Test of Sphericity; $p < .05$). Engagement to and disengagement from threat were examined using paired-samples *t* tests. Higher accuracy on valid threat versus neutral trials indicates facilitated engagement to threat cues, whereas lower accuracy on invalid threat versus neutral trials indicates difficult disengagement from threat cues. Cohen's *d* was calculated to determine whether expected differences had a small (0.20), medium (0.50), or large (0.80) effect size (Cohen, 1988).

Results

Self-Report Data

Table 1 provided the self-report data. The US (white noise stimulus) was perceived as highly unpleasant and threatening. As a manipulation check we compared expectancy and fear of the US between the two cues. Expectancy of the US was significantly larger for the CS+ than for the CS−, $t(18) = 13.61$, $p < .001$. In addition, fear of the US was significantly larger for the CS+ than for the CS−, $t(18) = 9.52$, $p < .001$. This indicates that our differential conditioning procedure was successful and that the CS+ was perceived as a threat cue in comparison with the CS−.

Behavioral Data

Overall, error percentages were very low ($M = 3.6$, $SD = 2.5$). In the baseline phase, there was only a significant Cue validity effect, $F(1, 18) = 22.36$, $p < .001$, indicating a lower percentage of errors in valid trials ($M = 1.8$, $SD = 2.3$) compared to invalid trials ($M = 10.6$, $SD = 8.9$). As colors were not conditioned yet in this phase, there were no effects of CS or Cue validity × CS ($F_s < 1$). In the acquisition phase, we found again a significant Cue validity effect, $F(1, 18) = 13.92$, $p < .01$, showing a lower percentage of errors in valid trials ($M = 2.0$, $SD = 1.5$) compared to invalid trials ($M = 7.0$, $SD = 6.3$). There was also a significant effect of CS, $F(1, 18) = 4.72$, $p < .05$, showing that more errors were made on CS+ trials ($M = 5.7$, $SD = 3.3$) than on CS− trials ($M = 3.3$, $SD = 1.8$). Of particular interest here however is the critical Cue validity × CS interaction, which was significant, $F(1, 18) = 5.09$, $p < .05$. This interaction was broke down into engagement and disengagement effects (see Table 2). We found no lower percentage of errors in valid CS+ trials than in valid CS− trials, $t(18) = -0.21$, $p = .836$ ($d = -0.05$; 95% CI: −0.68, 0.57), indicating no facilitated engagement to threat. However, we found that the proportion of errors was significantly higher in invalid CS+ trials compared to invalid CS− trials, $t(18) = 2.28$, $p = .035$ ($d = 0.61$; 95% CI: −0.03, 1.24), indicating difficult disengagement from threat.

Finally, we calculated correlations between trait anxiety and both attentional engagement to threat (valid CS− trials minus valid CS+ trials) and disengagement from threat (invalid CS+ trials minus invalid CS− trials). Both correlations were nonsignificant ($p > .10$).

Table 1
Means (and Standard Deviations) of Self-Report Data

	Experiment 1	Experiment 2
US unpleasant	7.6 (2.4)	8.3 (1.4)
US threatening	6.0 (2.8)	6.9 (2.6)
CS+ expectancy	7.2 (2.2)	7.1 (2.7)
CS− expectancy	0.3 (0.8)	0.5 (0.7)
CS+ fear	5.4 (2.4)	5.7 (2.9)
CS− fear	0.6 (1.5)	0.4 (0.9)
STAI-T	48.3 (3.4)	37.7 (6.2)

Discussion

Findings were largely in line with previous research using the emotional spatial cueing paradigm. In these studies, the cue validity effect (faster responses to valid trials than to invalid trials) was more pronounced for threat cues than for neutral cues, indicating increased allocation of attention to threat (Fox et al., 2001; Koster et al., 2005a, 2006; Van Damme et al., 2006; Yiend & Mathews, 2001). We were able to demonstrate a similar effect in terms of perceptual accuracy. Because our approach ruled out effects on the response stage of processing (see Prinzmetal et al., 2005), we believe that the present results are a genuine demonstration of increased allocation of attention to the location of a threatening cue.

Of particular interest is that we replicated several other studies (Fox et al., 2001, 2002; Yiend & Mathews, 2001) in showing that threat increased the cost of invalid cues. This indicates that difficulty disengaging attention from the location of threatening information occurs at the perceptual stage, that is, attention is focused on the location of the threat cue leading to diminished perceptual accuracy at the opposite location. Although a number of spatial cueing studies using fear-conditioned cues (Koster et al., 2004, 2005a; Van Damme et al., 2004, 2006) also showed that threat increased the benefit of valid cues, no indication of facilitated engagement by threat was found in the present study. In attentional bias studies relying on reaction times, the absence of engagement effects by threat has been explained by the very good performance in valid trials, hardly leaving room for improvement by the presence of threat (Fox et al., 2001). This explanation may also apply to our results, given the fact that accuracy was extremely high, particularly in valid trials (98%). To make our approach more sensitive and avoid ceiling effects in accuracy, we conducted a

Table 2
Means and Standard Deviations of Error Percentages in Different Trial Types

		Experiment 1	Experiment 2
Valid	CS+	2.1 (1.7)	5.4 (5.6)
	CS−	2.0 (1.9)	4.5 (4.7)
Invalid	CS+	9.4 (10.0)	37.0 (14.6)
	CS−	4.7 (3.8)	29.3 (12.8)

second experiment in which we attempted to increase the error rates by manipulating the presentation time of the targets.

Experiment 2

In this experiment, the same basic paradigm as in the first experiment was used, but with two methodological adaptations. First, we individually manipulated the presentation time of the targets o increase the sensitivity of the paradigm by increasing the error rates. More specific, we adapted target presentation time for each participant individually based upon performance during the exercise block: good performance resulted in shorter presentation times, whereas poor performance resulted in longer presentation times. Second, we decided to use geometrical forms instead of arrows as targets, because arrows connote a spatial direction. This could possibly result in some form of target-location compatibility: when the direction of the target is valid (invalid) with its position on the screen, this could lead to facilitation (inhibition). Although it is unlikely that such compatibility effect can account for the findings reported in the first experiment—the allocation of different target types to different spatial locations was counterbalanced—it still might have resulted in less reliable data. Therefore, we replaced the arrows by nondirectional targets (three different geometrical forms).

Method

Participants

Thirty undergraduate psychology students (9 males, 21 females; mean age $= 18.10$, $SD = 0.71$) from Ghent University participated to fulfill course requirements. The study protocol was approved by the ethical committee of the Faculty of Psychology and Educational Sciences at Ghent University. All participants gave informed consent and were free to terminate the experiment at any time.

Behavioral Task

Again, the spatial cueing task was used. However, there were two important differences as compared to Experiment 1. First, instead of arrows geometric forms were used as targets, which could be a triangle, a square, or a pentagon. Participants were instructed to indicate which figure was presented by pressing the corresponding button on an RB-530 Cedrus response box. Again, accuracy instead of speed was emphasized. Second, to control for ceiling effects in accuracy, presentation time of the target stimuli was individually determined based on participants' performance during the exercise block. After a small pilot study using the new version of the paradigm, 150 milliseconds was used as the starting presentation time in the exercise block. This presentation time could be adapted twice: after half of the exercise block and at the end of the exercise block. When accuracy was lower than 50%, presentation time was increased by 25 milliseconds. When accuracy was higher than 75%, presentation time was decreased by 25 milliseconds. Consequently, during the experimental blocks, presentation time of the targets could individually vary between 100 and 200 milliseconds. In the current experiment, the mean presentation time was 120 milliseconds, with a standard deviation of 21 milliseconds and a range between 100 and 175 milliseconds.

Procedure and Statistics

These were the same as in Experiment 1, with the sole exception that the exercise block now consisted of 40 instead of 20 trials, which was necessary to allow the individual adaptation of the presentation times of targets. Inspection of the data showed that the individual determination of target duration did not have the required effect for two participants. These participants made no errors at all on valid trials, which we actually tried to avoid. Therefore, data from both participants were excluded from further analyses.

Results

Self-Report Data

Table 1 provided the self-report data. The US was perceived as highly unpleasant and threatening. As a manipulation check, we compared expectancy and fear of the UCS between the two cues. Expectancy of the US was significantly larger for the CS+ than for the CS−, $t(27) = 11.81$, $p < .001$. In addition, fear of the US was significantly larger for the CS+ than for the CS−, $t(27) = 9.41$, $p < .001$. This indicates that our differential conditioning procedure was successful and that the CS+ was perceived as a threat cue in comparison with the CS−.

Behavioral Data

Overall, error percentages were much higher than in the first experiment ($M = 19.6$, $SD = 5.7$). In the baseline phase, only a significant Cue validity effect, $F(1, 27) = 133.60$, $p < .001$ emerged, indicating a lower percentage of errors in valid trials ($M = 5.4$, $SD = 4.0$) compared to invalid trials ($M = 34.6$, $SD = 12.9$). As colors were not conditioned yet in this phase, there were no effects of CS or Cue validity × CS ($F_s < 1$). In the acquisition phase, we found again a significant Cue validity effect, $F(1, 27) = 123.26$, $p < .001$, showing a lower percentage of errors in valid trials ($M = 5.0$, $SD = 4.5$) compared to invalid trials ($M = 33.1$, $SD = 12.2$). However, there was also a significant effect of CS, $F(1, 27) = 9.85$, $p < .01$, showing that more errors were made on CS+ trials ($M = 21.2$, $SD = 8.0$) than on CS− trials ($M = 16.9$, $SD = 6.5$). Of particular interest is the significant Cue validity × CS interaction, $F(1, 27) = 8.50$, $p < .01$. This interaction was broke down into engagement and disengagement effects (see Table 2). In valid trials, the proportion of errors was not lower for CS+ cues than for CS− cues, $t(27) = -0.97$, $p = .342$ ($d = -0.17$; 95% CI: -0.70, 0.35), indicating no facilitated engagement to threat. However, we found that the proportion of errors was significantly higher in invalid CS+ trials compared to invalid

CS− trials, $t(27) = 3.27$, $p = .003$ ($d = 0.56$; 95% CI: 0.02, 1.09), indicating difficult disengagement from threat.

Finally, we calculated correlations between trait anxiety and both attentional engagement to threat (valid CS− trials minus valid CS+ trials) and disengagement from threat (invalid CS+ trials minus invalid CS− trials). Both correlations were nonsignificant ($p > .10$).

Discussion

The results are closely in line with the findings of the first experiment. Again, it was shown that perceptual accuracy was modulated by threatening spatial cues. In addition, the engagement-disengagement pattern obtained was similar to Experiment 1. Although we used a more sensitive paradigm to reduce ceiling effects, accuracy on valid trials was again not affected by the threat value of the cues, indicating no effects on the engagement component. On invalid trials, accuracy was substantially lower when cues were threatening than when cues were neutral, indicating difficult disengagement from threat cues.

By manipulating the presentation time of the targets, we were able to make our paradigm more sensitive. Although the shorter presentation times substantially reduced accuracy, it has to be noted that this effect was more pronounced for the invalid trials than for the valid trials. On the valid trials, the number of errors was about 5% (in comparison with 2% in the first experiment). Although this is still a low error rate, one would expect effects of threat beginning to emerge in the expected direction, which was not the case.

General Discussion

Biased attention to threat stimuli is considered an etiological and maintaining factor in a large class of anxiety disorders (Eysenck, 1997; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Williams et al., 1997). This assumption has resulted in extensive research efforts with various experimental paradigms. One particularly elegant paradigm is the emotional modification of the spatial cueing paradigm, because it allows differentiating between the attentional components of engagement and disengagement (Posner & Peterson, 1990). Typical for studies using the spatial cueing paradigm to examine biased attention to threat is that the conclusions are based upon reaction time data, obtained from either speeded detection or speeded discrimination tasks. We have identified two potential problems in this approach. First, reaction times may not be well suited for detecting biases in populations characterized by overall slow reaction speed or psychomotor slowing, because biases have been shown to be short-lived (e.g., Koster et al., 2007). Second, in speeded spatial cueing tasks, studies typically demonstrate effects of threat on reaction times but not on accuracy, indicating effects on the response stage of processing rather than at the perceptual stage (Prinzmetal et al., 2005).

To investigate effects of threat cues on the perceptual level of processing, we performed two experiments using a perceptual accuracy version of the spatial cueing paradigm. To prevent response stage effects, we used cues that were spatially informative, and we explicitly instructed participants to focus on accuracy and not speed. Across two experiments differing in target stimuli, presentation time of targets, and overall error rates, highly similar results were found. Threatening cues enhanced spatial cueing effects in terms of perceptual accuracy. There was no difference in accuracy between threat cues and neutral cues when targets were presented on the expected location (valid cues). However, when targets were presented on the unexpected location (invalid cues), the percentage of errors was significantly larger in threat trials than in neutral trials. This indicates a difficulty disengaging attention from a location containing threatening information. In other words, attention was prioritized to the location of the threat cue, making it more difficult to correctly identify the target stimulus at the opposite location. However, attention to the location of the threat cue did not result in better identification of subsequent targets presented at that location. These findings are similar to the conclusions of several studies relying on reaction times as a measure of attention (Fox et al., 2001; Koster et al., 2004; Van Damme et al., 2006; Yiend & Mathews, 2001).

Although it is tempting to conclude that only the disengagement component of attention matters, caution is required. A number of methodological issues may account for the absence of engagement effects in the current study. For instance, it has been argued that performance on valid trials is usually very good and that this hardly leaves room for improvement by the presence of threat (Fox et al., 2001). This explanation might particularly apply to the results in our first experiment, in which performance on valid trials was nearly perfect. By manipulating the presentation time of targets in the second experiment, we attempted to increase error rates. This manipulation was successful as there was an overall substantial reduction in accuracy. Nevertheless, the error rate in valid trials was still low (about 5%) and we cannot be certain that this was sufficient to allow the detection of beneficial effects of threat upon engagement. As this may limit the usefulness of this task in future research, more work is needed to refine the paradigm so that engagement and disengagement effects have equal chances to be detected. One possibility that comes in mind is further decreasing the presentation time of targets. Although this might adequately reduce ceiling effects in valid trials, one could expect that accuracy on invalid trials will drastically decrease and eventually reach chance level, which might become problematic for interpreting disengagement effects. Perhaps in future experiments it should be considered using different presentation times for targets in valid and invalid trials based upon performance in an extended exercise block, to reach an "ideal" accuracy level (e.g., between 80 and 90% on valid trials and between 60% and 70% on invalid trials). Another possibility is working with degreaded target stimuli or using targets that are perceptually more similar than the different geometrical forms in the present task.

Another important issue is that the interpretation of data obtained from the emotional exogenous cueing paradigm, and particularly the differentiation between engagement and disengagement effects, is liable to criticism. As pointed out by Yiend and Mathews (2001), responses to targets are generally slower when preceded by threatening cues relative to neutral cues. Mogg, Holmes, Garner, and Bradley (2008) persuasively demonstrated that such response interruption leads to artificially increased response times to both valid threat trials—resulting in an underestimation of the engagement effect—and invalid threat trials—resulting in an overestimation of the disengagement effect. Although our paradigm seems to get round this problem by relying on accuracy instead of response speed, it still has to be noted that we found a significant main effect of CS in both experiments, with lower accuracy on threat trials than on neutral trials. This suggests that general interference by threatening information might not be limited to reaction time effects. At present, it is not clear how overall accuracy in our study could have been affected by threat. One possible mechanism is an anxiety-related decrease in attentional control (Eysenck, Derakshan, Santos, & Galvo, 2007). More specific, processing efficiency might have been negatively affected as a result of anxiety evoked by the task-irrelevant threatening stimulus, leading to impaired task performance. However, more research is needed to clear out this issue and its potential impact upon this particular paradigm.

We also have to keep in mind that several spatial cueing studies have reported that threat cues can facilitate target processing in valid trials. It is interesting to examine which task parameters are necessary to allow the detection of engagement effects. One important difference between our study and some of the studies showing engagement effects is the use of central instead of peripheral cues (see Fox et al., 2007; Mathews et al., 2003). It is possible that tasks using central cues are more sensitive in detecting engagement effects. However, it should be noted that also a number of spatial cueing studies using peripheral fear-conditioned cues (Koster et al., 2004, 2005a; Van Damme, Crombez, & Eccleston, 2004, 2006) showed facilitated engagement by threat. Note that cueing effects in those particular studies might have been confounded by spatial stimulus-response mapping (Lu & Proctor, 1995). It could be argued that engagement effects reported there do not reflect a genuine perceptual mechanism but rather the modulation of stimulus-response mapping by threatening cues (Schrooten & Smulders, 2007). However, more specific research is needed to allow any firm conclusion about this.

The findings have both theoretical and clinical relevance. First, the results further corroborate the conclusion from previous work in this area. The modulation of spatial attention by threatening cues also affects perceptual accuracy. This shows a more complete picture of how our attention system processes threatening information and allows further refinement of cognitive models of threat processing (e.g., Mogg & Bradley, 1998). Second, our findings confirm pronounced difficulty disengaging as a potentially important component of biased attention to threat. Important to note is that the effect sizes for the disengagement effect in the present experiments (Cohen's *d* of 0.61 and 0.56) are substantially higher than those obtained in spatial cueing studies relying on reaction times, indicating the sensitivity of the paradigm. Effect sizes for disengagement effects were small (Cohen's *d* between 0.20 and 0.30) in other studies using fear-conditioned cues (Koster et al., 2004, 2005a; Van Damme et al., 2004, 2006). In addition, in studies using pictorial cues in high anxious samples (Koster et al., 2006, 2007; Yiend & Mathews, 2001) effect sizes for disengagement effects were rather small (Cohen's *d* between 0.30 and 0.40).

There are a number of issues which need to be considered when drawing conclusions from the current study. First, cautiousness is required in generalizing the results, because we used small samples of undergraduate students. Replication of the findings in larger nonclinical and clinical samples is necessary. Second, we used cues that were fear-conditioned by means of aversive white noise. It is important that future studies utilize other threatening stimuli that have more ecological validity. Third, we did not include control conditions in which a nonthreatening stimulus was used as US. However, we refer to previous spatial attention studies that included such control condition (Koster et al., 2004; Van Damme et al., 2004), and showed that the effects were threat-specific. Fourth, it has to be noted that the attention effects in both experiments were not related to the level of trait anxiety. A plausible explanation for this is that the noise stimulus was highly unpleasant for all participants, decreasing the chance of interindividual variance. Also, note that the level of trait anxiety was high, particularly in the first experiment. It is possible that our results reflect an anxiety-specific difficulty disengaging attention from threat cues. In future studies it would be interesting to compare the effects of threatening cues on perceptual accuracy between selected groups of high and low anxious individuals. Despite these limitations, we believe that the perceptual accuracy approach presented here might prove a meaningful contribution to the attentional bias literature on both a theoretical and methodological level.

References

Armony, J. L., & Dolan, R. J. (2002). Modulation of spatial attention by fear-conditioned stimuli: An event-related fMRI study. *Neuropsychologia, 40,* 817–826.

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & van Yzendoorn, M. H. (2007). Threat-related attentional bias in anxious and non-anxious individuals: A meta-analytic study. *Psychological Bulletin, 133,* 1–24.

Bögels, S. M., & Mansell, W. (2004). Attention processes in the maintenance and treatment of social phobia: Hypervigilance, avoidance and self-focused attention. *Clinical Psychology Review, 24,* 827–856.

Calvo, M. G., & Avero, P. (2005). Time course of attentional bias to emotional scenes in anxiety: Gaze direction and duration. *Cognition & Emotion, 19,* 433–451.

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences.* San Diego, CA: McGraw-Hill.

Cooper, R. M., & Langton, S. R. H. (2006). Attentional bias to angry faces using the dot-probe task? It depends when you look for it. *Behaviour Research and Therapy, 44,* 1321–1329.

Crawford, L. E., & Cacioppo, J. T. (2002). Learning where to look for danger: Integrating affective and spatial information. *Psychological Science, 13,* 449–453.

De Clercq, A., Crombez, G., Roeyers, H., & Buysse, A. (2003). A simple and sensitive method to measure timing accuracy. *Behavior Research Methods, Instruments & Computers, 35,* 109–115.

Eccleston, C., & Crombez, G. (1999). Pain demands attention: A cognitive-affective model on the interruptive function of pain. *Psychological Bulletin, 125,* 356–366.

Eysenck, M. W. (1997). *Anxiety and cognition: A unified theory.* Hove: Erlbaum.

Eysenck, M. W., Derakshan, N., Santos, R., & Galvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion, 7,* 336–353.

Fox, E., Mathews, A., Calder, A. J., & Yiend, J. (2007). Anxiety and sensitivity to gaze direction in emotionally expressive faces. *Emotion, 7,* 478–486.

Fox, E., Russo, R., Bowles, R., & Dutton, K. (2001). Do threatening stimuli draw or hold attention in subclinical anxiety? *Journal of Experimental Psychology, 130,* 681–700.

Fox, E., Russo, R., & Dutton, K. (2002). Attentional bias for threat: Evidence for delayed disengagement from emotional faces. *Cognition & Emotion, 16,* 355–379.

Kornblum, S., Hasbroucq, T., & Osman, A. (1990). Dimensional overlap:

Cognitive basis for stimulus-response compatibility: A model and taxonomy. *Psychological Review, 97,* 253–270.

Koster, E. H. W., Crombez, G., Van Damme, S., Verschuere, B., & De Houwer, J. (2004). Is attention drawn to signals of imminent threat? *Emotion, 4,* 312–317.

Koster, E. H. W., Crombez, G., Van Damme, S., Verschuere, B., & De Houwer, J. (2005a). Signals for threat modulate attentional capture and holding: Fear-conditioning and extinction during the exogenous cueing task. *Cognition & Emotion, 19,* 771–780.

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

Koster, E. H. W., Crombez, G., Verschuere, B., Vanvolsem, P., & De Houwer, J. (2007). A time course analysis of attentional cueing by threatening scenes. *Experimental Psychology, 54,* 161–171.

Koster, E. H. W., Verschuere, B., Crombez, G., & Van Damme, S. (2005b). Time course of attention to threat in high and low trait anxiety. *Behaviour Research and Therapy, 43,* 1087–1098.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1990). Emotion, attention and the startle reflex. *Psychological Review, 97,* 377–398.

Lu, C. H., & Proctor, R. W. (1995). The influence of irrelevant location information on performance: A review of the Simon and spatial Stroop effects. *Psychonomic Bulletin and Review, 2*, 174–207.

MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology, 95,* 15–20.

Mathews, A., Fox, E., Yiend, J., & Calder, A. (2003). The face of fear: Effects of eye gaze and emotion on visual attention. *Visual Cognition, 10,* 823–835.

Mathews, A., & Mackintosh, B. (1998). A cognitive model of selective processing in anxiety. *Cognitive Therapy and Research, 22,* 539–560.

Mogg, K., & Bradley, B. P. (1998). A cognitive-motivational analysis of anxiety. *Behaviour Research and Therapy, 36,* 809–848.

Mogg, K., Bradley, B. P., Miles, F., & Dixon, R. (2004). Time course of attentional bias for threat scenes: Testing the vigilance-avoidance hypothesis. *Cognition & Emotion, 18,* 689–700.

Mogg, K., Holmes, A., Garner, M., & Bradley, B. P. (2008). Effects of threat cues upon attentional shifting, disengagement, and response slowing in anxious individuals. *Behaviour Research and Therapy, 46,* 656–667.

Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology, 32,* 3–25.

Posner, M. I., & Peterson, S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience, 13,* 25–42.

Prinzmetal, W., McCool, C., & Park, S. (2005). Attention: Reaction time and accuracy reveal different mechanisms. *Journal of Experimental Psychology: General, 134,* 73–92.

Salemink, E., van den Hout, M. A., & Kindt, M. (2007). Selective attention and threat: Quick orienting versus slow disengagement and two versions of the dot probe task. *Behaviour Research and Therapy, 45,* 607–615.

Santangelo, V., & Spence, C. (2008). Crossmodal attentional capture in an unspeeded simultaneity judgement task. *Visual Cognition, 16,* 155–165.

Schrooten, M. G. S., & Smulders, F. T. Y. (2007). A Simon-effect for threat-related stimulus content. *Journal of Behavior Therapy and Experimental Psychiatry, 38,* 121–132.

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., & Posner, M. I. (1999). Emotional modulation of attention orienting: A classical conditioning study. *Scandinavian Journal of Psychology, 40,* 91–99.

Stormark, K. M., Nordby, H., & Hugdahl, K. (1995). Attentional shifts to emotionally charged cues: Behavioural and ERP data. *Cognition and Emotion, 9,* 507–523.

Van Damme, S., Crombez, G., & Eccleston, C. (2004). The anticipation of pain modulates spatial attention: Evidence for pain-specificity in high-pain catastrophizers. *Pain, 111,* 392–399.

Van Damme, S., Crombez, G., Hermans, D., Koster, E. H. W., & Eccleston, C. (2006). The role of extinction and reinstatement in attentional bias to threat: A conditioning approach. *Behaviour Research and Therapy, 44,* 1555–1563.

Van Damme, S., Lorenz, J., Eccleston, C., Koster, E. H. W., De Clercq, A., & Crombez, G. (2004). Fear-conditioned cues of impending pain facilitate attentional engagement. *Neurophysiologie Clinique/Clinical Neurophysiology, 34,* 33–39.

Van der Ploeg, H. M., Defares, P. B., & Spielberger, C. D. (1980). *Handleiding bij de Zelf Beoordelings Vragenlijst*. [Manual for the Dutch adaptation of the STAI-Y]. Lisse: Swets & Zeitlinger.

Vuilleumier, P. (2005). How brains beware: Neural mechanisms of emotional attention. *Trends in Cognitive Sciences, 9,* 585–594.

Williams, J. M. G., Watts, F. N., MacLeod, C., & Mathews, A. (1997). *Cognitive psychology and emotional disorders* (2nd ed.). Chichester, UK: Wiley.

Yiend, J., & Mathews, A. (2001). Anxiety and attention to threatening pictures. *Quarterly Journal of Experimental Psychology A, 54,* 665–681.

Received July 9, 2007
Revision received May 9, 2008
Accepted July 28, 2008 ■