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Does Imminent Threat Capture and Hold Attention?

Ernst H. W. Koster, Geert Crombez, Stefaan Van Damme, Bruno Verschuere, and Jan De Houwer
Ghent University

According to models of attention and emotion, threat captures and holds attention. In behavioral tasks, robust evidence has been found for attentional holding but not for attentional capture by threat. An important explanation for the absence of attentional capture effects is that the visual stimuli used posed no genuine threat. The present study investigated whether visual cues that signal an aversive white noise can elicit attentional capture and holding effects. Cues presented in an attentional task were simultaneously provided with a threat value through an aversive-conditioning procedure. Response latencies showed that threatening cues captured and held attention. These results support recent views on attention to threat, proposing that imminent threat captures attention in everyone.

Over the past 20 years, a wealth of research has been done on visual attention to threat. It is generally accepted that the attentional system, normally involved in the pursuit of goal-directed behavior, is equipped to detect threatening information very rapidly and even preattentively (Esteves, Dimberg, & Öhman, 1994). The detection of threat leads to an immediate fear response and the direction of attention toward the source of danger. Several models of attention to threat have postulated that, because of its obvious survival value, the direction of attentional resources to imminent threat is a phylogenetically old mechanism that is present in everyone (Mathews & Mackintosh, 1998; Mogg & Bradley, 1998).

However, the evidence for attentional capture by threat in the general population is rather limited. Attentional capture in “normal/nonanxious” individuals has commonly been studied through cognitive-experimental paradigms. Two behavioral tasks are particularly relevant for this discussion. First, the attentional search task has been used to examine attentional capture by threat (Fox et al., 2000; Öhman, Flykt, & Esteves, 2001; Öhman, Lundqvist, & Esteves, 2001; Tipples, Young, Quinlan, Broks, & Ellis, 2002). In this task, participants are required to search a threatening stimulus (e.g., angry faces) embedded in an array of neutral or positive stimuli. Facilitated attentional search has been found for angry faces (e.g., Fox et al., 2000) and for snakes and spiders (Öhman, Flykt, & Esteves, 2001). However, the attentional search task is a relatively complex paradigm, and the attentional capture effect is partly determined by the surrounding stimuli, which raises the problem that response latencies may reflect both attentional capture by threat and attentional holding by the distracting stimuli.

A second line of studies have applied an emotional modification of the exogenous cueing task (Posner, 1980), which provides a less problematic measure of attentional capture because only one stimulus is presented each time (see Derryberry & Reed, 1994). This task has been used extensively to investigate covert orienting to peripheral presented cues and allows for distinguishing between attentional capture and attentional holding by threat. Using this task, Fox, Russo, Bowles, and Dutton (2001) found no support for attentional capture by threat over four experiments. Instead, they found that threat modulated attentional holding. Their results have been replicated consistently in a variety of studies (Fox, Russo, & Dutton, 2002; Tipples & Sharma, 2000; Yiend & Mathews, 2001). However, Stormark, Nordby, and Hugdahl (1995) did find some indication for attentional capture, but they used generally positive and negative words that were not threat-related. In the present study, we examined whether attentional capture ef-

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Ernst H. W. Koster, Geert Crombez, Stefaan Van Damme, Bruno Verschuere, and Jan De Houwer, Department of Psychology, Ghent University, Ghent, Belgium.

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Correspondence concerning this article should be addressed to Ernst H. W. Koster, Department of Psychology, Ghent University, Henri Dunantlaan 2, B-9000 Ghent, Belgium. E-mail: ernst.koster@ugent.be

fects by threat can be demonstrated using the exogenous cueing task.

Importantly, the lack of evidence for attentional capture by threat in the modified cueing paradigm may be related to the nature of the stimuli that were used in previous studies on attention to threat. Given the limited nature of attentional resources, threat needs to exceed a critical threshold value before it captures attention (Mathews & Mackintosh, 1998; Mogg & Bradley, 1998). The verbal and pictorial stimuli commonly used in research on attention to threat pose no genuine risk for the occurrence of an aversive event (Stormark, Hugdahl, & Posner, 1999) and may, therefore, not exceed the threshold to elicit attentional capture effects.

To overcome this problem, aversive-conditioned stimuli can be presented in an attentional task. In this way, stimuli acquire a signal value for the occurrence of an aversive event. In two experiments, Stormark and colleagues (Stormark & Hugdahl, 1996; Stormark et al., 1999) presented cues (conditioned stimuli [CS+] vs. CS−) that were differentially conditioned to an aversive burst of white noise (unconditioned stimulus [UCS]) in the exogenous cueing task. In this task, participants have to respond to a target, presented at the same (valid) or opposite (invalid) location of a cue. Normally, attention is allocated to the location of the cue, leading to facilitated responding on validly compared with invalidly cued targets. In the emotional adaptation of the exogenous cueing task used by Stormark and colleagues, attentional capture by the CS+ would be reflected in facilitated responding to the valid CS+ trials compared with valid CS− trials. Attentional holding of the CS+ would delay responding to the invalid CS+ trials compared with the invalid CS− trials. Stormark and colleagues found in both studies that target detection was faster on invalid CS+ trials, as compared with invalid CS− trials, whereas no differential cueing effects were found on the valid trials. According to Stormark et al., these results imply that participants shifted their attention away more rapidly from the CS+ cues compared with the CS− cues.

These results are at odds with the idea that threat signals capture and hold attention. However, there are several difficulties in relating the data obtained by Stormark et al. (Stormark & Hugdahl, 1996; Stormark et al., 1999) to models of attention to threat. First, the attentional task was performed after the conditioning phase, which may have decreased the signaling function of the CS+. Second, the time between cue onset and target onset was 600 ms, which may have caused reversed-attentional cueing effects (Posner, Rafal, Choate, & Vaughn, 1985). Recently, Armony and Dolan (2002) overcame these problems by conditioning angry faces to white noise during a visual dot probe task. They found that individuals selectively attended the CS+ cues that were presented very briefly (50 ms). Unfortunately, the dot probe task does not allow the distinguishing between attentional capture and holding (see Fox et al., 2001; Koster, Crombez, Verschuere, & De Houwer, in press). In the present study, we applied an aversive-conditioning procedure during the exogenous cueing task to provide the CS+ cue with an imminent threat value. On some trials, the CS+ was followed by an aversive burst of white noise, whereas the CS− was followed by a neutral tone. The CSs were presented briefly (200 ms).

Method

Participants

Thirty-four Flemish undergraduate students (28 women and 6 men; mean age = 18.12 years, *SD* = 0.48) participated to fulfill course requirements. All participants gave their informed consent and were free to terminate the experiment at any time. Participants had normal or corrected-to-normal vision.

Materials and Procedure

Participants were tested individually in a sound-attenuated room.

Manipulation check. To check the effectiveness of the conditioning procedure, the UCS expectancy was assessed by using 11-point numerical graphical rating scales (0 = *not at all,* 10 = *very strongly*). Participants reported to what extent they expected the UCS after the CS+ and after the CS− at the end of the acquisition phase.

Perceived characteristics of the UCS. Characteristics of the UCS were assessed after the acquisition phase using similar graphical rating scales. Participants had to indicate to what extent they found the UCS aversive and whether they were fearful of the UCS at presentation of the CS+.

Exogenous cueing paradigm. The attentional task was programmed using the INQUISIT Millisecond software package (Inquisit, 2001) and ran on a S710 Compaq Deskpro computer, with a 72 Hz, 17-in (43-cm) color monitor.

All stimuli were presented against a black background. On every trial, a white fixation cross was presented in the middle of the screen, along with two white rectangles (4.8 cm high × 6.5 cm wide), one to the left and one to the right of a fixation cross (duration of 500 ms). The middle of the rectangles was 9.2 cm from the fixation cross. Cues and targets were presented within these two rectangles. Cues consisted of two colored slides (pink or green) with the same size as the white rectangles. Which color frame functioned as the CS+ or CS− was counterbalanced across participants. Targets were black squares (1.1 cm × 1.1 cm). The UCS consisted of a 200-ms white-noise burst delivered through a headphone at an intensity of 100 dBA. Noise stimuli of this intensity and duration are aversive but not painful or physiologically harmful (Hobbs, 1990). The neutral tone consisted of a 1000 Hz stimulus, presented for 200 ms at an intensity of 71 dB.

The sequence of events on a test trial (see Figure 1) consisted of a 500-ms presentation of the fixation cross and white rectangles. Then, a cue appeared that was blanked out after 200 ms. The target was presented 14 ms after the cue offset and remained on screen until a response was made. Upon responding, the next trial started immediately. The CSs were followed by the auditory stimuli at a partial reinforcement ratio of 3:1 on valid and invalid trials. On reinforced CS+ and CS− trials, the auditory stimuli were presented 200 ms after target offset.

Of the test trials, 75% were validly cued and 25% were invalidly cued. The CS+ and CS− were presented equally often, in a fixed random order, with the constraints of maximal three consecutive similar presentations of CS type (CS+/CS−) and maximal three consecutive presentations of the target on the same location. To check for cue responding, catch trials were presented. These were trials in which a cue was not followed by a target and no response had to be made. Furthermore, to motivate participants to maintain their gaze at the middle of the screen, on some trials the fixation cross was replaced by a digit (5 mm high) presented for 100 ms, after which no CS or auditory stimulus followed (digit trials). Participants were instructed to report the digit aloud, but these verbal responses were not registered.

Practice phase. Participants were informed that an attentional task and auditory stimuli would be presented. The noise bursts and the neutral tone were presented once to familiarize participants with them. Hereinafter, participants gave a written informed consent. They were seated at approximately 60 cm from a computer screen to perform the cueing task. All further instructions were presented on the computer screen. Participants were asked to respond as quickly as possible without sacrificing accuracy to the location of the target by pressing one of two corresponding keys on a standard (AZERTY) keyboard. They were informed that a cue would precede the presentation of the target and that the cue would correctly predict the location of the target on most, but not all, trials. Participants practiced the attentional task during 10 trials. They were told that during the practice phase, no auditory stimuli would be presented.

Baseline phase. This phase consisted of 54 trials (24 CS+, 24 CS−, 3 catch, and 3 digit trials). Participants were informed that no auditory stimuli would be presented.

Acquisition phase. Participants were informed that one of the cues was a predictor of the noise burst, whereas the other cue predicted the neutral tone. To

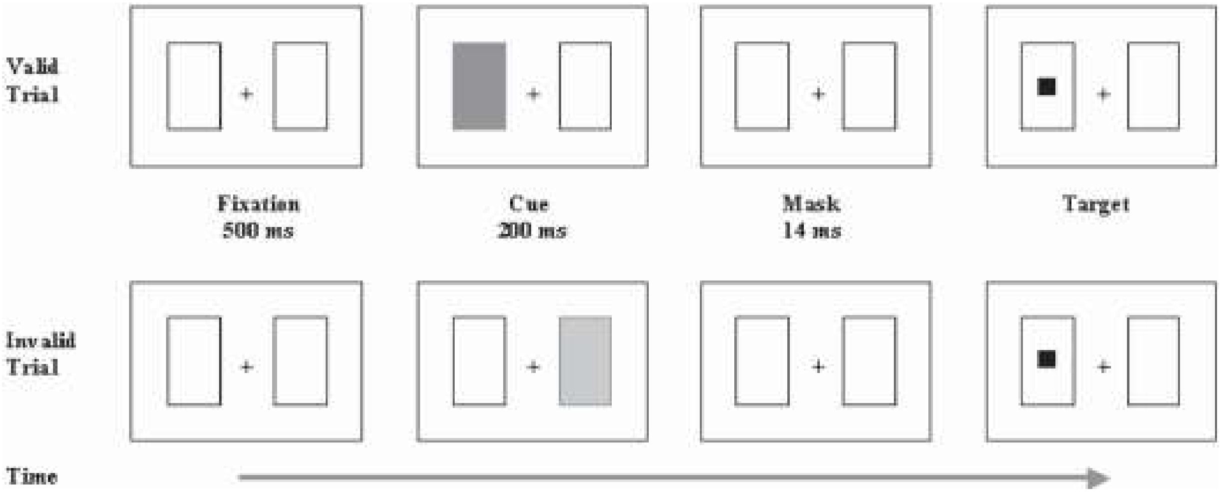

Figure 1. Schematic overview of valid and invalid trial sequences.

facilitate the detection of the contingency between the CS+ and the UCS, the acquisition phase started with two trials in which the CS+ was followed by the UCS. After this, 108 trials (48 CS+, 48 CS−, 6 catch, and 6 digit trials) were presented.

Results

Self-Report Data

UCS expectancy ratings revealed strong differential conditioning effects. Expectancy of the UCS at the end of the acquisition phase was significantly stronger after the presentation of the CS+ ($M = 6.79$, $SD = 1.95$) than after the CS− ($M = 1.82$, $SD = 2.22$), $t(33) = 8.89$, $p < .001$. Participants rated the UCS as aversive ($M = 6.12$, $SD = 2.25$) and were fearful of the UCS at presentation of the CS+ ($M = 5.68$, $SD = 2.58$).

Reaction Time (RT) Data

On the test trials, very few errors were made (0.9%). RTs shorter than 150 ms or longer than 1,000 ms were removed from the data (0.6%). *Individual outliers* were defined as RTs that deviated more than 3 standard deviations from the individual mean latency time and were also removed (2.5%). During the acquisition phase, participants responded on 7.4% of the catch trials. The mean number of responses on CS+ (3.4%) and CS− (3.9%) catch trials did not differ significantly ($t < 1.0$), indicating that the cues did not differ to the extent to which they induced a tendency to give a response.

We performed a 2 (experiment phase: baseline phase, acquisition phase) × 2 (CS type: CS+, CS−) × 2 (validity: valid trial, invalid trial) repeated measures analysis of variance (ANOVA) on the RTs. There was a strong validity effect, $F(1, 33) = 386.28$, $p < .001$, $\eta_P^2 = .92$, illustrating the basic exogenous cueing effect: Responding was significantly faster on valid trials ($M = 345$ ms, $SD = 39$) than on invalidly cued trials ($M = 408$ ms, $SD = 42$).

Of particular importance in this study was the significant three-way interaction between experiment phase, validity, and CS type, $F(1, 33) = 10.24$, $p < .05$, $\eta_P^2 = .24$. We found two other interaction effects that were subsumed under the three-way interaction: Experiment Phase × Validity, $F(1, 33) = 21.85$, $p < .001$, $\eta_P^2 = .40$; Validity × CS Type, $F(1, 33) = 4.77$, $p < .05$, $\eta_P^2 = .13$; all other effects: *F*s < 1. Figure 2 illustrates the RTs on valid and invalid trials as a function of CS type and experiment phase. To further clarify attentional capture and holding by the CS+ in the acquisition phase compared with the baseline phase, we performed 2 (experiment phase) × 2 (CS type) ANOVAs for valid and invalid trials.

Attentional capture. The 2 × 2 ANOVA on valid trials revealed a main effect of experiment phase, $F(1, 33) = 8.13$, $p < .01$, $\rho_p^2 = .20$, with overall faster responding in the acquisition phase ($M = 336$, $SD = 46$) compared with the baseline phase ($M = 354$, $SD = 50$). We found a nonsignificant effect for cue type, $F(1, 33) = 3.37$, $p = .075$, $\eta_P^2 = .09$. Participants responded faster on trials containing the CS+ cue ($M = 342$, $SD = 37$) compared with the CS− cue ($M = 348$, $SD = 41$). As predicted, the interaction between

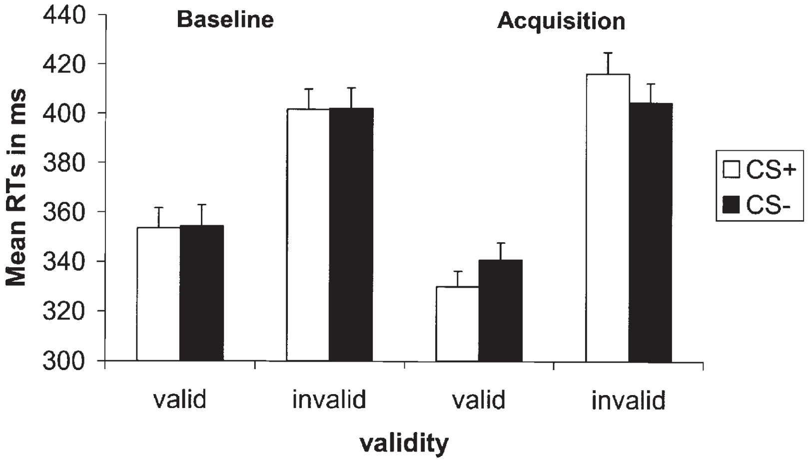

Figure 2. Mean reaction times (RTs) and standard errors (in ms) as a function of experiment phase, cue validity, and conditioned stimulus (CS) type.

experiment phase and cue type was significant, $F(1, 33) = 5.45, p < .05, \eta_P^2 = .14$. At the baseline phase, *t* tests revealed no significant differences between responding on valid CS+ ($M = 354$ ms, $SD = 48$) and valid CS− trials ($M = 354$ ms, $SD = 51$; $t < 1$). At the acquisition phase, participants responded more quickly to the valid CS+ trials ($M = 330$ ms, $SD = 34$) than to valid CS− trials ($M = 341$ ms, $SD = 40$), $t(33) = -2.58, p < .05$, indicating attentional capture by the CS+.

Attentional holding. The 2 × 2 ANOVA on invalid trials revealed no main effects (*F*s < 1.5) but did reveal a significant interaction effect between experiment phase and cue type, $F(1, 33) = 4.15, p = .05, \eta_P^2 = .11$. The *t* tests we used to examine attentional holding indicated no significant differences ($t < 1$) in responding to invalid CS+ trials ($M = 402$ ms, $SD = 47$) compared with invalid CS− trials ($M = 402$ ms, $SD = 48$) at the baseline phase. At acquisition, however, participants were significantly slower to respond to invalid CS+ trials ($M = 417$ ms, $SD = 52$) than to invalid CS− trials ($M = 405$ ms, $SD = 54$), $t(33) = 2.90, p < .01$. This indicates an attentional holding effect by the CS+.

Discussion

Successful responding to threat is largely dependent on rapid, efficient extraction of critical information in the environment (Öhman, Flykt, & Lundqvist, 2000). This is the first study to demonstrate modulation of both the capture and holding component of visual attention by signals for threat. More importantly, we have replicated these results in further studies, which attests to the reliability of our findings (Koster, Crombez, Van Damme, Verschuere, & De Houwer, 2003). The present results suggest that attentional modulation to signals for imminent threat is a normal and adaptive mechanism present in all of us, as is assumed in recent models on attention to threat (Mathews & Mackintosh, 1998; Mogg & Bradley, 1998).

Results of the present study provide important additional evidence to support the notion of attentional capture by threat. Our results are in line with neuroscientific evidence in animals and humans showing that threat is processed very rapidly through a “quick and dirty” subcortical pathway, followed by a slower and more precise appraisal processing involving cortical structures (see LeDoux, 1996; Morris, Öhman, & Dolan, 1998). Armony and Dolan (2002) recently applied a dot probe task with briefly presented (50 ms) fear-conditioned angry faces in a neuroimaging study. They observed that presentation of fear-conditioned angry faces leads to enhanced activity of the amygdala and the extrastriate visual cortex. The modulation of spatial attention by fear-conditioned stimuli leads to enhanced activity in regions of frontal and parietal cortices as well as the lateral orbitofrontal cortex. The latter structure was hypothesized to be an interface between information about the affective valence of a stimulus produced by the amygdala to the cortical structures involved in spatial attention (Armony & Dolan, 2002, p. 824). The observed attentional capture effect for threat signals in this study suggests that previously neutral stimuli that are fear-conditioned may be processed in a similar way.

There are two main explanations why the visual stimuli used in this study captured attention, whereas other studies with the modified cueing paradigm (e.g., Fox et al., 2001; Yiend & Mathews, 2001) found no evidence for attentional capture by threat. First, the visual stimuli used in the present experiment directly signaled the possible occurrence of an aversive event. Second, the visual stimuli that we used were highly salient and simple, whereas in previous studies, more complex stimuli such as photographs of objects or faces were used. It is possible that our stimuli captured attention because they were easy to process.

The results of our study are limited in certain respects. First, a possible alternative explanation for the attentional capture effect may be provided. It could be argued that presentation of the CS+ cue elicited a motor response that caused the facilitation on valid trials. However, the analysis of the catch trials does not support this notion, as the number of responses on catch trials with the CS+ was not higher than on catch trials with the CS−. Furthermore, although we observed faster responding to the CS+ cue in the acquisition phase, we found no facilitation on invalid CS+ trials. Second, it is important to note that responding to the CS+ was compared with responding to the CS− (i.e., the stimulus that was followed by a soft tone). It is therefore not possible to exclude the possibility that the observed effects were due to attentional bias away from the CS− cue rather than an attentional bias toward the CS+ cue. However, from Figure 2 it is clear that, if anything, the CS− cue was more strongly attended during acquisition than during the baseline phase. Thus, the present attentional cueing by the CS+ cues may even be an underestimation of the actual attentional cueing effects. Third, studies using even shorter presentation times are necessary to elucidate to what extent attention can be modulated preattentively. Finally, studies using the attentional search have provided some evidence for attentional capture by negative and positive emotional cues (see Tipples et al., 2002). Future studies should also incorporate cues with a positive emotional valence to investigate to what extent attentional capture effects are specific for threat-related stimuli.

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