

Running head: THREAT INTERFERENCE IS MODULATED BY TOP-DOWN  
SET

The spider does not always win the fight for attention: Disengagement from threat is  
modulated by goal set.

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## Abstract

Stimulus-driven preferential attention to threat can be modulated by goal-driven attention (Hahn & Gronlund, 2007; Van Dillen, Lakens, & Van den Bos, 2011; Vogt, De Houwer, Crombez, & Van Damme, 2013). However, it remains unclear how this goal-driven modulation affects specific attentional components implied in threat interference. We hypothesize that goal-driven modulation most strongly impacts delayed disengagement from threat. A spatial cueing task was used that disentangles delayed disengagement from attentional capture by tightly manipulating the locus of attention at the time of target onset. Different top-down goals were induced by instructing participants to identify bird/fish targets (Experiment 1) or spider/cat targets (Experiment 2) among animal non-targets. Delayed disengagement from a non-target spider was observed only when the spider was part of the target set, not when it was task-irrelevant. This corroborates evidence that threat stimuli do not necessarily override goal-driven attentional control and that extended processing of threatening distractors is not obligatory.

*Keywords:* threat, fear, attention, goal-driven, stimulus-driven

The spider does not always win the fight for attention: Disengagement from threat is modulated by goal set.

We are generally able to exert control over where we direct our attention. However, objects in the visual world will, at times, drive our attention. By its nature this stimulus-driven attention may act in opposition to the goal-driven (i.e. top-down) control of attention. An ongoing debate on the nature of attentional control has raised the question whether attention to salient distracter stimuli is involuntary and driven solely by stimulus properties such as abrupt onsets (Schreij, Theeuwes, & Olivers, 2010; Yantis & Jonides, 1984), color, and salience (e.g. Belopolsky, Schreij, & Theeuwes, 2010; Posner, 1980; Theeuwes, 1994;), or is modulated by task goals. For example, salient but irrelevant distractors in spatial cueing have been shown to capture attention only when they contained a target feature (Folk, Remington, & Johnston, 1992). Folk et al. showed that a single abrupt-onset distractor captured attention if the target was a single abrupt-onset stimulus, but not when the target was a color singleton. Conversely, a color singleton distractor captured attention if the target was a color singleton, but not when the target was a single stimulus defined by its abrupt onset. Consequently, it has been argued that attentional capture is contingent on an attentional control setting for task-relevant properties (contingent attentional capture; Folk et al.). A large number of subsequent studies (e.g. Dombrowe, Donk, & Olivers, 2011; Eimer, Kiss, Press, & Sauter, 2009; Folk, Remington, & Wu, 2009; Irons, Folk, & Remington, 2011; Wolfe, Butcher, Lee, & Hyle, 2003) have supported that one's attentional set modulates distractor interference, thus advocating top-down modulation of attentional interference.

Against the background of the debate on the nature of attentional control, a series of studies have proposed that attention to threat stimuli is special and not

subject to top-down goal-related control that has been shown to modulate attention to other stimulus categories (e.g., abrupt luminance transients). Threat stimuli (e.g. spiders) have been shown to interfere with the task-relevant allocation of attention in high as well as low anxious volunteers. In visual search, threat targets are found faster than neutral targets (e.g. Öhman, Flykt, & Esteves, 2001; Rinck, Reinecke, Ellwart, Heuer, & Becker, 2005) and search for neutral targets is slower in the presence of threat distractors (e.g. Lipp & Waters, 2007). In studies using the dot-probe, responses to a neutral target are faster when it is displayed in the same location as a previously presented (non-informative) threat cue compared to when it is presented in the same location as a non-threat cue (Mogg & Bradley, 2006; Lipp & Derakshan, 2005).

The finding that threat stimuli can disrupt the goal-driven allocation of attentional resources has been interpreted repeatedly as support for an involuntary, bottom-up driven interference with goal directed attention (e.g. Isbell, 2006; LoBue & DeLoache, 2008; Luo et al., 2010; Öhman & Mineka, 2001). This proposed bottom-up driven interference is generally presumed to be mediated by a fast, subcortical route responsible for processing threat stimuli (LeDoux, 1996; 2000). The absence of goal-related top-down modulation of threat-related interference is advocated perhaps most strongly in the fear module account (Öhman & Mineka). This account as well as more recent neuroscience accounts (e.g. Luo et al.) propose that the fear system is (largely) encapsulated from top-down modulation. However, a number of recent studies have indicated that threat-related interference can be influenced by top-down goals. These studies show that threat interference is not observed when participants' goals compete with preferential attention to threat stimuli (Hahn & Gronlund, 2007; Van Dillen et al., 2011; Vogt et al., 2013). Hahn and Gronlund showed that preferential attention to angry faces in visual search is modulated by top-down search

goals: Angry faces received preferential attention (over happy faces) when they were the target but not when they were the distracter irrelevant to the task goal. In the same vein, using the dot-probe paradigm Vogt et al. showed that directly goal-relevant stimuli received preferential attention over threat stimuli (indicating an imminent burst of white noise). In line with these studies, the current study assesses whether threat interference can be modulated by top-down goals by varying top-down task goals across experiments.

Moreover, the current study was designed to disentangle whether threat interference reflects attentional capture by threat (the rapid initial orienting of attention towards a threat stimulus) or delayed attentional disengagement (the slowed subsequent withdrawal of attention from threat; see e.g. Brockmole & Boot, 2009). Much of the previous research on threat-related interference has studied the effects of threat stimuli on an aggregate of attentional processes and has not been diagnostic to the distinction between effects of threat capture and disengagement. This in part reflects on a failure to control the locus of attention at trial onset in most experimental paradigms, i.e. attention could be at the location of the threat stimulus or elsewhere (Fox et al., 2001; Fox, Russo, & Dutton, 2002; Hahn & Gronlund, 2007; Lipp & Waters, 2007). For example, Hahn and Gronlund showed that the presence of an angry face distracter in visual search slowed target responses, but this could be due to the threat distracter capturing attention or it delaying disengagement once attended. Endeavoring to dissociate attentional capture and delayed disengagement, Fox et al. employed an exogenous cueing paradigm where a single cue (angry or neutral face) was presented in one of two possible locations and followed by a neutral target (a square or circle) in either the cued location (valid trials) or non-cued location (invalid trials). On valid trials, target detection was unaffected by cue valence, which could be

interpreted as evidence against speeded attentional capture by threat cues. However, given that neutral target stimuli were characterized by abrupt onsets, the contingent capture account (Folk et al., 1992) would predict that any cue characterized by an abrupt onset would capture attention. As both angry and neutral face cues had an abrupt onset they would both be expected to capture attention and a failure to find superior capture by angry face cues as compared to neutral face cues could simply indicate that both cues captured attention efficiently, leaving no room for superior capture by threat cues (Todd & van Gelder, 1979). Additionally, the study used a cue target asynchrony of 300 ms, a window long enough for multiple attentional processes to take place, increasing the likelihood that the paradigm may not provide a sensitive measure of capture. On invalid trials, target detection was significantly slower following threat cues, taken to indicate slowed disengagement from threat cues. However, Mogg, Holmes, Garner, and Bradley (2008) questioned whether this differential response slowing could reflect on differences in motor processes as well as effects of spatial attention. Subsequent studies have claimed evidence for slowed disengagement from threat stimuli (Belopolsky, Devue, & Theeuwes, 2011; Koster, Crombez, Verschuere, & De Houwer, 2004), whereas some studies have also claimed evidence for speeded capture by threat (West, Anderson, & Pratt, 2009; Yiend, 2010). However, the results provided are difficult to interpret as these studies did not control the (initial) allocation of attention, making it difficult to disentangle capture and disengagement reliably.

It also remains unexplored whether attentional capture and attentional disengagement are differentially affected by stimulus-driven and goal-driven processes. The current study addressed this question in a cuing paradigm that allows for the disentanglement of attentional capture and disengagement while

simultaneously varying task goals so that the threat stimulus is either part of the target set or not. We used a spatial cueing paradigm based on Folk et al. (1992) in which subjects searched for a green animal silhouette among three white non-target animal silhouettes. On some trials one of the white, non-target stimuli was the threat stimulus (spider silhouette). Prior to target presentation, a target-colored cue (four green dots) was presented around one possible target location. According to contingent capture theory, attention should be allocated to the target-color cue location producing a cueing effect and consequently response time should be faster when the subsequent target appears at the cued location rather than at one of the other locations. If the threat stimulus automatically captures attention, irrespective of top-down set, then trials on which it is present as a non-target should show little or no advantage for the cued location, as attention will have been drawn away from the cued location to the threat stimulus. In addition, if threat stimuli delay the disengagement of attention, then it should take longer to respond to the target presented at a non-cued location when the threat stimulus occurs at the cued location compared to a non-threat stimulus. The target display was presented briefly (47 ms) to create a task that was attentionally demanding and to make it difficult to attend to all 4 silhouettes sequentially before making a target response. In such a task set-up stimuli will have to compete for attentional resources which is critical to observing attentional interference according to biased competition models (Mathews & Mackintosh, 1998; Yiend, 2010).

In Experiment 1, we assessed whether a threat-related non-target silhouette (white spider) would interfere with target identification more than a non-threat non-target silhouette (white cat) when the target set (bird versus fish) did not include the spider. If the spider silhouette captured attention, then it should slow target responses

when present at any location in the display. If attention takes longer to disengage from the spider silhouette, then it should slow target responses when presented at the cued location to which attention has been drawn.

## Experiment 1

### *Method*

#### *Participants.*

Twenty University of Queensland students (17 women; age range = 17-24 years,  $M = 19$  years) volunteered in Experiment 1 in return for course credit. Their fear of spiders was assessed with the Spider Phobia Questionnaire (SPQ; Klorman, Hastings, Weerts, Melamed, & Lang, 1974). The SPQ is a self-report questionnaire that consists of 31 true/false items concerning spiders. The total score can range from 0-31, with higher scores indicating more fear of spiders. The total SPQ scores in the current experiment ranged from 2 to 24 ( $M = 13.10$ ;  $SD = 6.91$ ). These scores are indicative of a sample in which a number of volunteers likely suffer from arachnophobia, while the majority of volunteers display a wide range of non-clinical spider fear (Fredrickson, 1983; Muris & Merckelbach, 1996). No participants were excluded based on their SPQ score.

#### *Materials and apparatus*

The target stimuli were two green animal silhouettes, one depicting a bird and one depicting a fish (see Figure 1 for an example). The non-target stimuli were five white animal silhouettes, one each depicting a bird, fish (identical to the green target silhouettes, except in color), a horse, cat, and spider. The animals were equated in size ( $M = 505$  pixels) and presented on a black background. Each target and distractor silhouette was displayed within a placeholder box. Placeholder boxes were defined by

a white outline consisting of 114 x 88 pixels and measuring 3 x 2.6 cm. The spatial cue consisted of the outline of one of the boxes turning green with four green dots appearing around this box. The color of the spatial cue was identical to that of the target animals. As the cue contains the critical element (green color) on which target identification is based, the cue should produce a reliable cueing effect on target identification time even though it is uninformative as to the actual target location. Stimulus presentation was controlled by DMDX (Forster & Forster, 2003). Stimuli were presented on a Dell Optiplex 780 computer with a 16-in. color monitor, a resolution of 1,024 x 768 pixels, and a refresh rate of 85Hz.

*Procedure.*

During a single session participants completed a computerized spatial cueing task followed by a pen-and-paper version of the SPQ (Klorman et al., 1974) used to assess fear of spiders. Participants were informed that a spider, cat, horse, bird, and fish silhouette would be depicted during the spatial cueing task.

*Spatial cueing task.*

Throughout each trial, a central fixation cross and four placeholder boxes were presented in a cross-like arrangement (see Figure 1). Each placeholder box was positioned with its nearest corner 6 cm away from the center of the fixation cross. Each trial consisted of three different displays presented in a sequence of 5 frames as shown in Figure 1. The fixation display consisted of the central fixation cross and four rectangular boxes. The cue display was identical to the fixation display with the cue - 4 green dots - displayed around one of the four boxes with equal probability. The target display consisted of the fixation display with four animal silhouettes, one depicted in each box. On each trial, three white non-target silhouettes and one green target silhouette were displayed. The bird, fish, and horse silhouettes were presented

on each trial whereas the spider and cat silhouettes were presented on half of the trials. The bird silhouette was the target on half of the trials and the fish silhouette on the remaining and the animal that was not the target was displayed as a non-target. Horse, spider, and cat silhouettes were always non-targets. The different silhouettes were displayed with equal probability in each box. Depending on which silhouette was displayed in the cued box, four types of trials can be distinguished. On valid-cued trials a green target silhouette was displayed in the cued box. On invalid horse-cued and invalid spider/cat-cued trials a white non-target silhouette - horse, spider, or cat respectively - was displayed in the cued box. On foil-cued trials a silhouette with a target identity - bird or fish - but non-target color - white - was displayed in the cued box. Figure 1 shows an example of an invalid spider-cued trial with a fish target. Each participant completed 12 practice and 96 test trials. Valid-, invalid horse-, invalid spider/cat-, and foil-cued trials each made up 25% (24 trials) of the total number of trials. Trial presentation order was randomized for each participant.

Each trial started with the fixation display, presented for 882 ms. Then the cue display was presented for 82 ms followed by the fixation display for 82 ms. Subsequently, the target display was presented for 47 ms. Each trial ended with the presentation of a blank screen for 882 ms (see Figure 1). Participants were instructed to indicate as quickly and accurately as possible whether the green target silhouette was a bird or a fish by pressing the left or right shift keys. Allocation of target animal to shift key was counterbalanced across participants. From the moment of target presentation participants had a maximum of 2,900 ms to make a response. Response feedback (correct or incorrect) was given on practice trials only.

### *Results*

The average target identification time for each condition is presented in Figure

2. A 4 [Cued Item: valid, invalid-horse, invalid-spider/cat, foil]  $\times$  2 [Threat: spider distracter, cat distracter] repeated measures ANOVA on target identification time showed a main effect of Cued Item,  $F(3,17) = 15.477, p < .001, \text{partial } \eta^2 = .732$ . Target identification was faster on valid-cued than on invalid cued trials (horse cued:  $t(19) = 4.311, p < .001$ ; spider/cat cued:  $t(19) = 4.806, p < .001$ ). Thus the cue was effective in manipulating attention. Also, target identification was slower on foil-cued than on invalid spider/cat-cued trials ( $t(19) = 2.239, p = .037$ ). This indicates that cued silhouettes displayed in the non-target color interfered more with target identification when they had a target identity (foils) compared to when they had a non-target identity. The ANOVA showed no main effect for Threat,  $F(1,19) = .782, p = .388, \text{partial } \eta^2 = .040$ , nor the expected Cued Item by Threat interaction,  $F(3,17) = .818, p = .502, \text{partial } \eta^2 = .126$ . No difference was observed between trials on which a spider and cat non-target silhouette was presented, regardless of whether the spider/cat silhouette was cued or not (valid cued:  $t(19) = .886, p = .386$ ; invalid horse cued:  $t(19) = 1.934, p = .068$ , invalid spider/cat cued:  $t(19) = .507, p = .618$ ; foil cued:  $t(19) = .541, p = .595$ ). Thus, Experiment 1 provided no evidence for delayed disengagement from or speeded capture by the spider silhouette distracter.

## Experiment 2

The absence of spider interference in Experiment 1 indicates that it is possible to maintain an attentional set for color in the presence of a threat stimulus. This finding is not in line with the notion that threat stimuli will necessarily capture attention or interfere with top down attentional set. Instead, it suggests that subjects can ignore threat stimuli when they are able to use a neutral feature (color) to determine where the target is. That is, an attentional set for the task-relevant property can override the response to a threat stimulus. This is consistent with previous evidence for goal-driven modulation of capture by threat-relevant stimuli (Hahn & Gronlund, 2007; Van Dillen et al., 2011; Vogt et al., 2013). In the current paradigm, these results could be taken to mean that the emotional content of the spider silhouette could be ignored. When subjects can select on the basis of color it may be possible for attention to focus narrowly on the item with the target color, effectively short-circuiting the deeper analysis of the non-targets to reveal semantic or emotional content. However, what if the spider would be included in the target set? Evidence suggests that in similar spatial cueing paradigms with threat-neutral stimuli, the identity of attended non-targets can slow response times to identify a target when they are incompatible with the response to be made (Remington, Folk, & McLean, 2001; Remington & Folk, 2001; Lachter, Remington, & Ruthruff, 2009). In Experiment 2 we explore whether the emotional content of an attended item will interfere with target identification when the item is part of the target set. Additionally, we collected threat ratings for the silhouettes to confirm that spider silhouettes are more threatening than cat, bird, and fish silhouettes. In Experiment 2 the target and distractor animals from Experiment 1 were switched, rendering the spider part of the target set. Thus, in Experiment 2, we assessed whether the same threat-related spider

silhouette distracter would interfere with target identification when the green target set (spider versus cat) did include the spider. The non-target spider and cat silhouette again could be presented at the cued (attended) location, as well as a non-cued (unattended) location.

### *Method*

#### *Participants.*

Twenty University of Queensland students (16 women; age range = 17-26 years,  $M = 19$  years) volunteered in Experiment 2 in return for course credit. Their scores on the SPQ (Klorman et al., 1974) ranged from 0 to 27 ( $M = 11.75$ ;  $SD = 7.53$ ). This distribution of scores on the SPQ is indicative of a sample in which a number of volunteers may suffer from spider phobia, while the majority of volunteers display a wide range of non-clinical spider fear (Fredrickson, 1983; Muris & Merkelbach, 1996). No participants were excluded based on their SPQ score.

#### *Procedure.*

In addition to the spatial cueing task and the SPQ (Klorman et al., 1974) participants also completed threat and arousal ratings for all silhouettes.

#### *Spatial Cueing Task.*

The procedure and spatial cueing task in this experiment were identical to Experiment 1, with the following exceptions. Instead of green bird and fish target silhouettes, we used green spider and cat target silhouettes. The white horse silhouette was no longer included, because a spider and a cat silhouette (one being the target, the other being a non-target) were presented on each trial. This set-up resulted in three different trial types. On valid-cued trials the green target silhouette - spider or cat - was presented in the cued box. On invalid-cued trials (50%) a white non-target silhouette - bird or fish - was presented in the cued box. On foil-cued trials (25%) a

silhouette with a target identity – spider or cat - but non-target color - white - was presented in the cued box. Valid- and foil-cued trials each made up 25% (24 trials) of the 96 trials, while invalid-cued trials made up 50% (48 trials).

*Silhouette ratings.*

The pen and paper silhouette questionnaire consisted of the spider, cat, bird, and fish silhouettes as used in the spatial cueing task. Each silhouette was followed by 2 questions: ‘How scary do you find this stimulus?’ and ‘how arousing do you find this stimulus?’. Participants answered each question by putting a mark on a 17 cm Visual Analogue Scale (VAS) ranging from ‘Not at all scary’ to ‘Very scary’ or ‘Not at all arousing’ to ‘Very arousing’. Ratings were scored by measuring the number of millimeters from the leftmost point of the scale to a participant’s mark and not subjected to transformations. Therefore higher numbers reflect silhouettes that were rated as more threatening/arousing.

*Results*

*Silhouette ratings.*

Spider silhouettes ( $M = 47.650$ ,  $SD = 45.535$ ) were rated as more threatening than cat ( $M = 11.950$ ,  $SD = 21.751$ ;  $t(19) = 3.780$ ,  $p < .05$ ), bird ( $M = 16.050$ ,  $SD = 32.263$ ;  $t(19) = 3.279$ ,  $p < .05$ ), and fish silhouettes ( $M = 8.200$ ,  $SD = 18.572$ ;  $t(19) = 4.108$ ,  $p < .05$ ), while the other silhouettes did not differ from one another in rated threat value (cat versus bird:  $t(19) = 1.062$ ,  $p = .301$ ; cat versus fish:  $t(19) = 1.430$ ,  $p = .169$ ; bird versus fish:  $t(19) = 1.399$ ,  $p = .178$ ). Spider silhouettes were rated as more arousing ( $M = 40.550$ ,  $SD = 36.203$ ) than fish silhouettes ( $M = 21.350$ ,  $SD = 34.139$ ;  $t(19) = 2.205$ ,  $p < .05$ ), and there was a trend towards them being more arousing than cat ( $M = 24.800$ ,  $SD = 23.025$ ;  $t(19) = 2.013$ ,  $p = .058$ ) and bird silhouettes ( $M = 26.550$ ,  $SD = 31.683$ ;  $t(19) = 2.205$ ,  $p = .058$ ). The other silhouettes did not differ

from one another in rated arousal value (cat versus bird:  $t(19) = .327$ ,  $p = .747$ ; cat versus fish:  $t(19) = .566$ ,  $p = .578$ ; bird versus fish:  $t(19) = .574$ ,  $p = .572$ ).

#### *Reaction time data.*

Average target identification times for all conditions are presented in Figure 3. A 3 [Cued Item: valid, invalid, foil]  $\times$  2 [Threat: spider distracter, cat distracter] repeated measures ANOVA on target identification time again showed a main effect of Cued Item,  $F(2,18) = 11.895$ ,  $p < .01$ , *partial*  $\eta^2 = .569$ . Relative to invalid trials, target identification was faster on valid-cued trials ( $t(19) = 4.870$ ,  $p < .001$ ) and slower on foil-cued trials ( $t(19) = 4.856$ ,  $p < .001$ ). No main effect of Threat was observed,  $F(1,19) = 3.847$ ,  $p = .065$ , *partial*  $\eta^2 = .168$ , providing no support for overall spider silhouette interference. However, the expected Cued Item  $\times$  Threat interaction,  $F(2,18) = 5.673$ ,  $p < .05$ , *partial*  $\eta^2 = .387$ , was observed. On invalid trials (fish or bird silhouette presented in the cued location), no difference emerged between spider and cat non-target trials ( $t(19) = 1.377$ ,  $p = .184$ ). Thus, Experiment 2 provides no evidence for attentional capture by the non-target spider silhouette if it was not cued. However, when the spider and cat non-target silhouettes were displayed in the cued location (foil trials), the spider silhouette slowed down target identification more than did the cat silhouette ( $t(19) = 3.333$ ,  $p = .003$ ; see Figure 3). Thus, Experiment 2 provides evidence for slowed attentional disengagement from the cued non-target spider silhouette.<sup>1</sup>

#### General Discussion

The spider silhouette was rated as more threatening (and arousing) than all other animal silhouettes. Delayed attentional disengagement from the non-target spider was observed when the spider was included in the target set (Experiment 2), but not when the spider was not included in the target set (Experiment 1)<sup>1</sup>. Thus,

when the spider was not included in the target set, it did not slow target identification even when attention was already at its location. In contrast, when the spider was included in the target set, the non-target spider did slow down target identification when it was presented at the cued location. These results indicate that delayed disengagement from a non-target spider was modulated by top-down attentional control and are inconsistent with solely bottom-up driven explanations of threat-related interference (Isbell, 2006; James, 1890; LoBue & DeLoache, 2008; Luo et al., 2010; Öhman & Mineka, 2001). The observed top-down modulation of delayed disengagement from threat is in line with explanations that allow for goal-driven modulation of attentional interference (e.g. Folk et al., 1992) and neuroscientific accounts that propose subcortical emotion processing as not encapsulated from cortical input (e.g. Pessoa & Adolphs, 2010; Tamietto & De Gelder, 2010).

Attentional capture by the non-target spider silhouette was not observed in either of the two experiments. Thus, when attention was at a location other than that of the non-target spider silhouette, the spider did not seem to affect target identification time in the current paradigm. This result does not preclude that capture would be observed if one were to employ a different paradigm or use more potent or realistic threat stimuli. Previous studies (Forbes, Purkis, & Lipp, 2010; Mermillod et al., 2010) have shown that threat-related interference is observed regardless of whether the threat stimuli are silhouette or more detailed stimuli, indicating that increased stimulus simplicity does not eliminate threat-related interference. In contrast to the current study, Forbes et al. demonstrated threat-related interference with silhouettes that were not included in the target set. However, Forbes et al. used a design that does not allow for the separation of capture and disengagement. Moreover, they employed a visual search task with an extended display time in which

inhibition of threat-related interference was not necessary to make a successful target response. In the current study, the four silhouettes were presented only briefly and thus competition for attentional resources was likely more intense. In order to carry out the task at hand successfully the target silhouette would have to receive sufficient attentional resources, leaving limited attentional resources for the other silhouettes. This would make it more difficult for a threat distracter to bias attention. One way in which the attentional system could ensure sufficient resources are allocated to the target stimulus is by adopting a strict top-down set and increasing the amount of top-down control on attentional allocation (Folk et al., 1992). Mermillod et al. (2010) showed that low-spatial-frequency information is sufficient for fast recognition of threat stimuli and that it may be particularly this information that provides rapid feed-forward input to the amygdala (Bocanegra & Zeelenberg, 2009; Vuilleumier, Armony, Driver, & Dolan, 2003). Nevertheless it is important for future studies to investigate whether top-down modulation is affected by the intensity of a threat stimulus and whether capture can be observed with more potent threat stimuli in the current cueing paradigm.

Delayed disengagement was found to depend on the relationship of the threat stimulus to the behavioral goals. This commitment of attention is a function of two factors: (1) the activity generated by a stimulus once it has been attended, which should be higher when the stimulus matches an active goal compared to when it is irrelevant to current goals; (2) The perceptual properties of other stimuli that may compete for attention (see e.g. Kastner & Ungerleider, 2000). In the current study, a non-attended green stimulus should provide stronger competition for attentional resources than a non-attended white stimulus, since the green color signals that this stimulus is relevant to the current goal of target identification. Similar factors

influence the allocation of visual spatial attention in other paradigms and they have received extensive attention in visual search (see e.g. Lipp & Waters, 2007). It is important to note that in our experiments when the cue drew attention to the location of a task-irrelevant threat stimulus (e.g., spider foil) the target frame contained a task-relevant feature singleton (e.g., green) to which attention was set to respond. In our case, then, the time to disengage represented a trade-off between the activation created by the foil stimulus and the ability of the target color to activate a preexisting attentional control setting. Here the silhouettes have no disadvantage in comparison to the more realistic stimuli because attention has already been directed to them by the cue. The current study is not able to disentangle the different stimulus-related forces that contribute to the observed interference by the threat stimulus. Threat value of a stimulus seems to be a main force, but previous research has also pointed to an important role for arousal and biological significance irrespective of valence (Brosch, Sander, & Scherer, 2007; Mourão-Miranda et al., 2003; Schimmack, 2005).

Additionally it is fair to assume that low-level stimulus characteristics like contrast and angles play a role in what we term threat interference too (Mermillod et al., 2010; Yiend, 2010; Wolfe et al., 2003). The current study shows that the observed threat interference is an attentional effect and not a motor effect (as proposed by e.g. Mogg et al., 2008) as threat interference is absent on trials where attention is already on the spider or cat target.

In summary, the current study is the first to assess threat interference in a procedure that controls the locus of attention at target onset, hence permitting the distinction between preferential attentional capture and delayed disengagement, while at the same time varying the specific top-down attentional set (by including the threat stimulus in the target set or not). The study found evidence for slowed disengagement

from a threat distractor only if the threat distractor was part of the top-down attentional set. This finding suggests that task goals modulate the ability of a threat stimulus to hold attention and that the systems that mediate emotional responses are not necessarily isolated from those that mediate cognitive processes.

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## Footnotes

<sup>1</sup> We obtained similar results in subsequent studies with more detailed threat stimuli. Detailed statistical results are available from the first author. Slowed attentional disengagement from the cued spider distracter was not correlated with SPQ score ( $r(20) = .227, p = .336$ ) or spider pictures' fear and arousal ratings (fear:  $r(20) = .05, p = .836$ ; arousal:  $r(20) = .156, p = .512$ ).

Figure Caption

*Figure 1.* A trial in the spatial cueing task in experiments 1 and 2 consisted of the following display sequence: fixation display, cue display, fixation display, target display, blank screen. The depicted trial is an invalid spider-cued trial with a fish target from Experiment 1.

*Figure 2.* Average target identification time for valid-cued, invalid horse-cued, invalid spider/cat-cued, and foil-cued trials with a spider versus cat distracter in Experiment 1. \*\* =  $p < .01$ .

*Figure 3.* Average target identification time for valid-cued, invalid-cued, and foil-cued trials with a spider versus cat distracter in Experiment 2. \*\* =  $p < .01$ .

Figure 1.

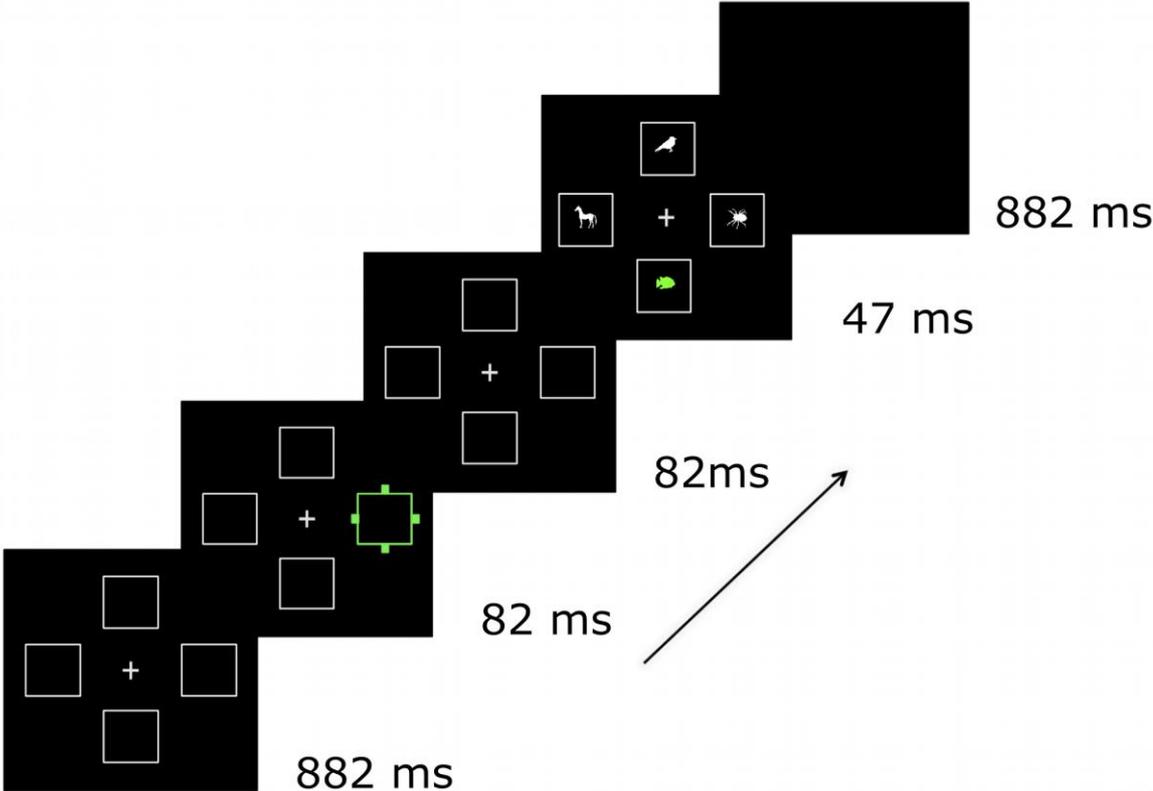


Figure 2.

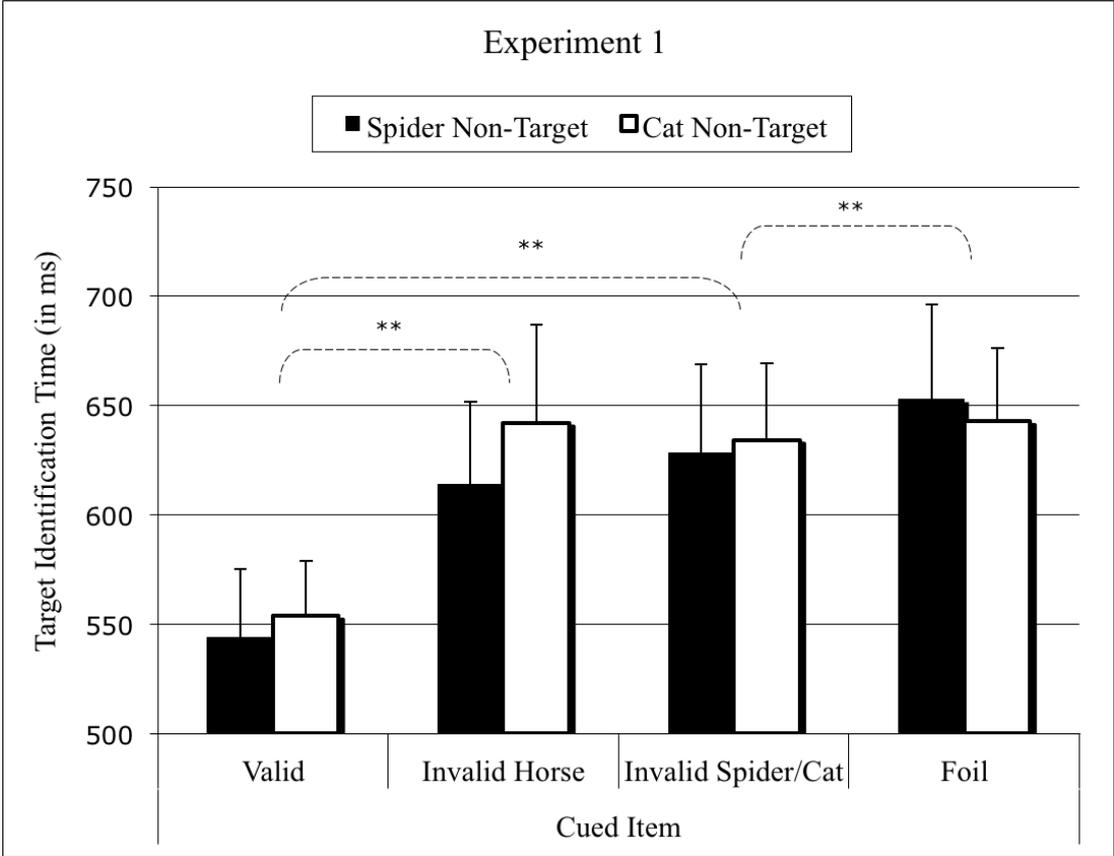


Figure 3.

