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Original Article

The Lurking Snake in the Grass: Interference of Snake Stimuli in Visually Taxing Conditions

Sandra Cristina Soares, Department of Education, University of Aveiro, Portugal; Institute of Biomedical Research in Light and Image, Faculty of Medicine, University of Coimbra, Portugal. Email: sandra.soares@ua.pt.

Abstract: Based on evolutionary considerations, it was hypothesized that humans have been shaped to easily spot snakes in visually cluttered scenes that might otherwise hide camouflaged snakes. This hypothesis was tested in a visual search experiment in which I assessed automatic attention capture to evolutionarily-relevant distractor stimuli (snakes), in comparison with another animal which is also feared but where this fear has a disputed evolutionary origin (spiders), and neutral stimuli (mushrooms). Sixty participants were engaged in a task that involved the detection of a target (a bird) among pictures of fruits. Unexpectedly, on some trials, a snake, a spider, or a mushroom replaced one of the fruits. The question of interest was whether the distracting stimuli slowed the reaction times for finding the target (the bird) to different degrees. Perceptual load of the task was manipulated by increments in the set size (6 or 12 items) on different trials. The findings showed that snake stimuli were processed preferentially, particularly under conditions where attentional resources were depleted, which reinforced the role of this evolutionarily-relevant stimulus in accessing the visual system (Isbell, 2009).

Keywords: snake detection theory, visual search, perceptual load

Introduction

Fear is a functional emotion that is activated in response to threat and serves to motivate the organism to cope with potentially deadly outcomes, promoting escape or avoidance (see Öhman and Mineka, 2001). Ancient sensory mechanisms, with an origin in organisms with primitive brains, evolved for rapid detection of what could turn out to be life-threatening events (e.g., encountering predators) (for a review, see Öhman, 2008). Such mechanisms developed in brains with restricted capacity for advanced cognitive elaboration in order to promote early defense recruitment and, therefore, provide an obvious survival benefit.

Previous studies appear to support the claim that fear stimuli are given special priority by the attention system both in children (e.g., LoBue and DeLoache, 2008), adult humans (Öhman, Flykt, and Esteves, 2001), and in lab-reared, snake-naïve monkeys (Shibasaki and Kawai, 2009). Danger or threat is a central parameter in these studies, and snakes and spiders constitute such stimuli, being among the most feared stimuli by humans according to epidemiological data (e.g., Agras, Sylvester, and Oliveau, 1969), and frequently represented in clinical animal phobias (APA, 2000). As the first modern predators of crown-group placental mammals (Isbell, 2006), snakes are regarded as the founding category of predatory fears. However, this does not seem to apply to spiders, for which the evolutionary argument is weaker. Emphasizing an important difference between snakes and spiders is encouraged by recent developments in evolutionary theory giving snakes an important role in the evolution of predatory fear in primates (Isbell, 2006). According to *Snake Detection Theory* (SDT) (Isbell, 2009), the necessity to detect potentially deadly snakes in visually demanding perceptual situations, in which they are camouflaged in foliage or vegetation, had a strong influence on the evolution of the outstanding visual abilities of the higher primates. Such an astute ability for visual detection, however, is less likely for spiders, which have provided considerably less of a predatory threat than snakes. Furthermore, few spiders produce venoms that are seriously damaging to primates, and they are dangerous primarily when they are on the body, when touch is a more important detection modality than vision. These considerations suggest that snakes and spiders share important features (e.g., both are animals capable of rapid unpredictable movements, and are both often feared by humans), yet appear to differ in the likelihood of an evolutionary association with predation on primates. Thus, a demonstration of more efficient detection of snakes than of spiders in visual scenes would involve a specificity that invites an evolutionary interpretation (see Isbell, 2009).

However, previous studies have typically collapsed snakes and spiders into one fear category (“fear-relevant stimulus”) (e.g., Öhman et al., 2001). To my knowledge, only a few studies have investigated differences between the attentional processing of snakes and spiders (Lipp and Waters, 2007; Soares, Esteves, Lundqvist, and Öhman, 2009). However, in these studies, the main goal was to investigate the effects of prior fear (snake and spider fear) in the attentional processing of the feared stimulus (e.g., snakes, for snake fearful individuals), compared to the fear-relevant but non-feared stimulus (e.g., spiders, for snake fearful participants) and the control stimuli. In the present study, the goal was to examine specific factors derived from the SDT (Isbell, 2009), which provides a theoretical rationale for expecting a stronger attentional effect produced by snakes than by spiders.

Even fewer studies have investigated whether the processing advantage for fear stimuli with a high ecological relevance (snakes) is dependent on perceptual load. Although a previous study from our lab has examined this factor (Soares et al., 2009), in that study we were interested in top-down controlled searches given our interest in specific fears. However, detecting cryptic snakes when attention is focused on information unrelated to snakes (e.g., foraging for food), and in a highly perceptually complex environment, is vital to ensure rapid and effective defensive responses. In threatening situations in which rapid recruitment of defensive mechanisms is required, it would not be appropriate to pursue a deep cognitive analysis prior to the activation of defenses. Evidence to date strongly

supports the notion that emotional stimuli are quickly detected by a subcortical circuit that is centered in the amygdala (LeDoux, 1996; Öhman, 2005). However, controversy surrounds the automaticity of the response to emotional stimuli and the role of attention in such processing, with some authors suggesting that privileged responses to emotional stimuli are independent of attention (see Dolan and Vuilleumier, 2003, for a review), while others provide evidence showing that this processing advantage to emotional stimuli dissipates with increased attention (reviewed by Pessoa and Ungerleider, 2004).

The aim of the present study was to experimentally test the evolutionary considerations regarding the role of snakes in visual attention in conditions where perceptual resources are depleted. Following the modified visual search task introduced by Miltner, Krieschel, Hecht, Trippe, and Weiss (2004), I asked participants to detect a neutral target stimulus (a picture of a bird) presented among a background of neutral stimuli (pictures of fruits). On some critical trials, one of the background fruit pictures was replaced with either a snake, a spider, or a mushroom. The perceptual load was manipulated by varying the set size of the visual display: small (6 items) and large (12 items) displays (cf. Lavie and Cox, 1997). I hypothesized an attentional priority to snakes, compared to the other fear-related stimuli (i.e., spiders), particularly in cluttered environments (e.g., among many distractor stimuli).

Materials and Methods

Participants

The participants included 60 women who were enrolled in several classes of graduate course programs at the University of Aveiro, Portugal. Their ages ranged from 18 to 38 years ($M = 23.63$, $SD = 6.05$). The recruitment strategy was to include participants with matched levels of fear of snakes and spiders and, in addition, participants with low to medium levels of both fears. This strategy resulted in roughly equivalent mean scores on the SNAQ ($M = 13.18$, $SD = 2.60$) and the SPQ ($M = 11.35$, $SD = 3.04$) questionnaires (Klorman, Weerts, Hastings, Melamed, and Lang, 1974).

Equipment and Materials

The task was programmed using the software Macromedia Director MX and was performed on a CRT 21-in. (53.34 cm) monitor, with a resolution of 1600 x 1200 pixels, and with a visible area of 19.7'' (50.04 cm). Reaction time (RT) data were collected by key presses via a standard computer keyboard, by using a key labeled "Target Absent" to be pressed when the participants did not perceive the target in the display, and a key labeled "Target Present" when the participants perceived the target in the display.

The pictures included in the task comprised 18 exemplars of each stimulus category (birds, fruits, spiders, snakes, and mushrooms) displaying the objects in their ecological environment in the centre of the picture. These were the same pictures as used by Soares et al. (2009), with bird pictures taken from the internet. Although it is not possible to completely control for all possible low-level visual confounds, the use of complex pictures represents a main advantage in this type of study as it confers more ecological validity. Moreover, extensive spatial frequency analyses were run to compare the different stimulus

categories, with no significant effects being obtained.

Procedure

Psychometric instruments. Fear of snakes and spiders was assessed by 30 and 31 true or false statements included in the SNAQ and SPQ, respectively. Each questionnaire was translated into Portuguese from those developed by Klorman et al. (1974), by using the forward and backward translation procedures. Tests with 633 undergraduate students showed that our Portuguese versions of both the SNAQ (Cronbach's $\alpha = .91$) and SPQ (Cronbach's $\alpha = .92$) are reliable (unpublished data).

Visual display. The visual displays included either 6 or 12 pictures, arranged along an imaginary circle around the fixation mark. Pictures were arranged in this way to control for the distance that the eyes had to move in the different set size conditions. The radius of the circle was the same for the two conditions, thus holding the demands of the main task constant across the different set sizes. The size of the whole display on the screen was 26.0 x 25.0 cm, and the size of each picture on the screen was 3.5 x 2.3 cm. The distance from the fixation point to the center of each one of the pictures was 11.5 cm. Participants were seated at a distance of 1 m from the computer screen.

Each visual display was announced by the appearance of a fixation mark (1 x 1 cm), presented at the center of the computer screen for 1000 ms. This was followed by the presentation of a visual display until the participant's response. Further, a 2000 ms inter-trial interval occurred before the reappearance of the fixation mark and the consequent initiation of a new trial.

Experimental conditions. Stimulus displays were constructed using five different categories of color pictures of snakes, spiders, mushrooms, fruits, and birds. The visual displays included pictures of fruits (background), and, amongst the background stimuli of half the images, a neutral target picture (a bird). Participants were presented with 192 trials, comprising 96 target present and 96 target absent trials, randomly assigned to each participant. In 36 target present and 36 target absent trials, an additional distractor picture (snake, spider, mushroom) was added, with equal probability of appearance for each of these distractor categories. In the remaining 60 of the target present and target absent trials, no distractor stimulus was presented. Both target and distractor positions were counterbalanced across trials with equal probability of appearing at one of six possible positions. Therefore, I included two within-participants factors, the type of distractor (snake, spider, mushroom, no distractor), and the set size of the displays (6 or 12 items).

Instructions. Informed consent was obtained before testing. Participants were then asked to find a position in which they could comfortably reach the two keys (labeled "Target Present" and "Target Absent") with their right and left index fingers. Written instructions for the visual search task were self-paced and emphasized that the participant's task was to determine, as quickly and accurately as possible, whether a target stimulus (bird) was present or absent among distractors (fruits). Participants were also informed that, in some trials, an additional discrepant picture (i.e., a distractor), of a snake, spider or mushroom, would be presented among the background stimuli (fruits). The instructions emphasized that although distractors could appear independently of the presence or absence of the target picture, the task was to decide upon the presence or absence of the target

picture (bird).

Participants were taken through a series of 15 practice trials, which included 9 displays with, and 6 displays without, a target stimulus. The configurations of the displays used in the practice trials were not included in the main task.

Design and statistical analysis. Only correct answers were included in the RT analysis, and outliers which were more than 3 standard deviations (SD) from the mean were replaced by the individual's mean \pm 3 SD. Reaction time data were log-transformed in order to meet the requirements of normally distributed data, although values were back-transformed to RTs (in ms) in the text and in the figures to facilitate interpretation of the data. I adopted the .05 significance level throughout all analyses.

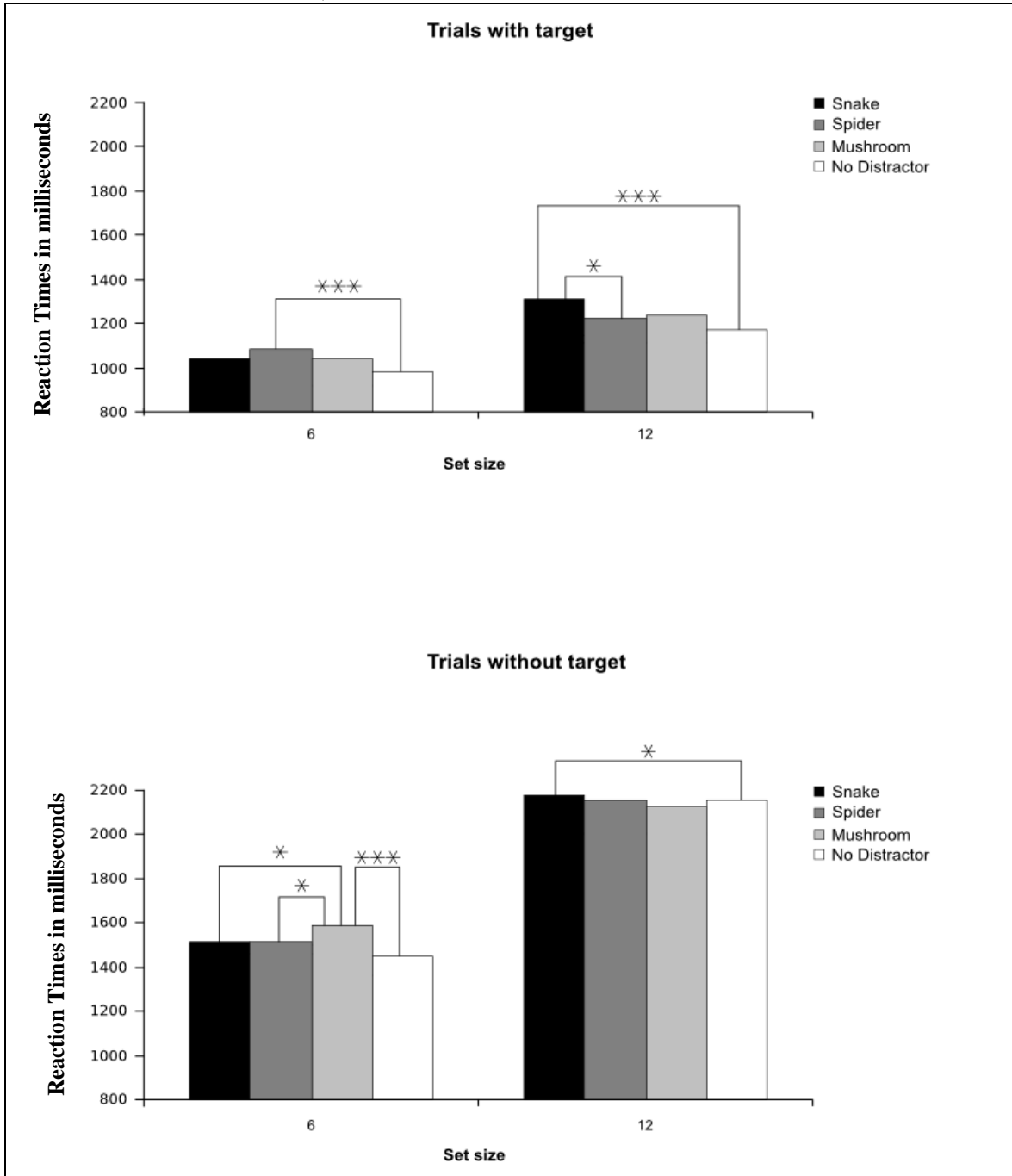
The designs were two factorial incorporating two within-participants (2 x 4) factors, the type of distractor (snake, spider, mushroom, no distractor) and the set size (6, 12). Analyses of Variance (ANOVAs) were run separately for correct RTs and for response accuracy and, within each set of data (RTs and accuracy), I ran independent analyses for trials with and without a target picture.

Results

Target-Present Trials

Reaction time data. The analysis showed that, overall, the presence of a distractor picture in the display (irrespective of the category) resulted in longer RTs and, therefore, in a larger interference with the main task, compared with the absence of a distractor stimulus ($F(3,174) = 13.41, p < .0001, \eta_p^2 = .19$). However, this effect was not dependent on the evolutionary relevance of the distractor stimulus, since the results showed that the presence of a snake distractor ($M = 1167$ ms) did not seem to significantly slow performance more than distractor pictures of spiders ($M = 1152$ ms) and mushrooms ($M = 1135$ ms). Importantly though, and as predicted, the results showed that for the larger displays (12 pictures) there were longer RTs for snakes ($M = 1309$ ms) compared with spider distractors ($M = 1226$ ms; $p < .05$), as evidenced by the interaction between set size and type of distractor ($F(3, 174) = 4.98, p < .01, \eta_p^2 = .08$). The difference between spider and mushroom distractors ($M = 1238$ ms) did not reach statistical significance. For the smaller displays, however, post hoc Tukey tests did not reveal significant differences between displays with snake ($M = 1041$ ms), spider ($M = 1083$ ms), or mushroom distractors ($M = 1041$ ms). However, spider distractors significantly differed from displays with no distractor stimuli ($p < .0001$), with the snake and mushroom conditions not reaching statistical significance ($p < .06$; see Figure 1).

Figure 1. Mean Reaction Times (RTs) in milliseconds (ms) to locate the presence or absence of a discrepant target (bird) in different distractor conditions (snake, spider, mushroom, and no distractor)



Note: The upper panel refers to the target-present conditions, as a function of the set size (6, 12). The lower panel represents the same variables but in the target-absent conditions. *** indicates $p < 0.001$, * indicates $p < 0.05$.

The results also showed that the overall reaction times were longer for the larger set size (with 12 pictures), compared with the smaller set size (with 6 pictures) (1236 ms vs. 1036 ms, respectively; $F(1, 58) = 186.78, p < .0001, \eta_p^2 = .76$).

Accuracy data. The response accuracy data showed lower accuracy for displays with fear pictures independently of their evolutionary relevance ($M = 92\%$, $M = 94\%$, for snakes and spiders, respectively), compared with displays with a neutral distractor ($M = 95\%$) and displays without a distractor picture ($M = 96\%$) ($F(3, 174) = 3.42, p < .05, \eta_p^2 = .06$), although a post hoc test Tukey did not reveal significant differences between these conditions.

Target-Absent Trials

Reaction time data. The results from the target-absent trials replicated the previous findings, showing a larger interference of distractors with the central search task, compared to trials that did not include such stimuli ($F(3, 174) = 12.12, p < .0001, \eta_p^2 = .17; p < .05$, according to Tukey test). Also corroborating the results from the target-present analysis, post hoc Tukey tests did not reveal significant differences in interference latencies between fear-relevant distractor pictures (snakes and spiders) and neutral ones (mushrooms). However, and also consistent with the previous results and our expectations, the interference from the different distractors varied as function of the set size, with snakes producing a larger interference (longer RTs) in the larger displays ($M = 2178$ ms) compared with displays with no distractor picture ($M = 2064$ ms; Tukey HSDs, $p < .05$). In the smaller displays, on the other hand, the interference effects, as revealed by longer RTs, showed that mushroom distractors ($M = 1591$ ms) produced the larger interference with the decision that no target picture was present in the display, compared to snake ($M = 1512$ ms; Tukey HSDs, $p < .05$), spider ($M = 1513$ ms; Tukey HSDs, $p < .05$), and no distractor conditions ($M = 1451$ ms; Tukey HSDs, $p < .0001$) ($F(3, 174) = 4.48, p < .01, \eta_p^2 = .07$; see Figure 1).

The results from the target-absent analysis also showed a main effect of the set size, with overall longer RTs for the larger displays (2131 ms vs. 1516 ms, respectively; $F(1, 58) = 1066.20, p < .0001, \eta_p^2 = .95$).

Accuracy data. The response accuracy data showed lower accuracy for displays with a spider distractor ($M = 98\%$), compared to displays with a snake ($M = 99\%$) or a mushroom distractor ($M = 99\%$), and displays without a distractor picture ($M = 99\%$) ($F(3, 174) = 2.95, p < .05, \eta_p^2 = .05$; with a post hoc Tukey test not revealing any significant differences).

Discussion

I investigated if the presence of unexpected snake stimuli, in comparison with spider and mushroom distractor stimuli, interfered with a primary visual search task that involved the detection of a neutral target (bird) presented among a background of neutral pictures (fruits), and whether perceptual load modulated this interference. In general, the results showed overall interference effects (larger RTs and lower accuracy) by the distractor conditions under both perceptual load manipulations (small vs. large displays),

compared to the baseline (i.e., displays without a distractor picture). Importantly, however, this effect was modulated by the perceptual load involved in the main search task and by the type of trials (target-present or target-absent trials). In the higher perceptual load conditions (larger set size) of the target-present trials, the presence of a snake distractor interfered with the main search task to a greater extent than did spider distractors and, to some extent, than mushroom distractors ($p < .07$). In the high-load condition of the target-absent analysis, this effect was also found but it was diluted, since snake distractors were related to greater interference effects, compared to the no-distractor condition, but did not differ from the spider and mushroom distractor conditions. In the low-load conditions (smaller set size), on the other hand, the somewhat privileged attentional capture by snake distractors was eliminated and results were shown to be quite inconsistent. In target-present trials, spider distractors produced the larger interference effects, compared with no-distractor displays, whereas in target-absent trials mushrooms produced the larger interference effects. Thus, part of the interaction between the type of distractor and perceptual load could be attributed to the more efficient detection of spiders and mushrooms in the low-load conditions of the target-present and target-present trials, respectively. Because of their more invariant shapes, spiders and mushrooms may in fact be more easily recognized under low-load conditions. Snakes, on the other hand, can be more or less straightly elongated, sinusoidally shaped, or coiled, which might delay confident recognition yet be sufficient as tags to capture attention when presented under high load conditions.

The ability to remain focused on a current task is relevant for appropriate cognitive functioning and, therefore, it is important to focus attention on critical elements of the environment while ignoring distracting information (e.g., Wolfe, 1998). Although previous studies on the role of perceptual load on the processing of distractor stimuli have suggested that the level of load in the processing of relevant stimuli critically determines interference from distractors (see Lavie, 1995, for a review), my findings showed that, overall, distractor stimuli always interfered with the search, independently of the level of load involved in the task. Importantly, there was an evident specificity in the type of distractor stimuli interfering with the task under the higher load conditions, with this effect being attributed to the most evolutionarily-relevant stimulus, snakes (in comparison with the other fear stimulus, spiders, and the neutral stimulus, mushrooms). This distracting effect of snakes under the high perceptual load condition seems to contradict the expected effects of perceptual load on distractor processing (cf. Lavie, 2005). Under conditions of high perceptual load such as those involved in the current task (large displays – 12 items), even though perceptual capacities were presumably exhausted, the processing of distractors was not inhibited for snakes, in contrast with interference from spiders and mushrooms that seemed to be dampened. Thus, spiders, compared to snakes, appear to be more dependent on attention, with the effects of interference with the main task being eliminated to a greater extent when these stimuli were deprived of attentional resources (i.e., in the higher-load conditions).

Based on the findings showing that the dependency of the load in distractor processing varies with the type of information to be processed, I suggest that distractor stimuli holding an evolutionary relevance (snakes) are processed regardless of the

perceptual load involved in the relevant task, whereas distractor fear stimuli lacking such importance (spiders) are only processed when the perceptual resources are not exhausted. Therefore, snake attentional capture, unlike spider capture, seems to be immune to conditions known to impede detection performance in visual search settings, such as elevated perceptual load (Lavie, 1995, 2005), assessed by using many background distractors (Duncan and Humphreys, 1989; Wolfe, 1998). In line with these findings are previous studies showing that snake stimuli require few attentional resources in order to be fully processed, with evidence suggesting that snakes are more resistant to extinction than neutral conditioned stimuli (Öhman and Soares, 1993), even when the snake stimuli are blocked from conscious perception (Öhman and Soares, 1994). However, these previous studies have lumped snakes and spiders together under the “fear-relevant” category, with possible dissociations between the two stimuli remaining unseen.

In summary, my results showed that the preferential detection of fear stimuli (snakes and spiders) under top-down controlled attention (Soares et al., 2009) is also observed in a stimulus-driven bottom-up mode. Thus, snakes and spiders seemed to capture attention not only when actively sought for, but also more automatically when occurring outside the spotlight of attention (bottom-up attention control). Although fear stimuli entering an attentional spotlight searching for something else can become immediate targets of defensive maneuvers, a snake in the path of an unsuspecting foot, for example, provides a more acute danger, and its quick, automatic detection would carry considerable adaptive value. More importantly, the findings also grant novel indications that detection of snakes appears somewhat less dependent on the perceptual load; snakes are specifically tuned to capture attention. My set of results suggests that it seems particularly important to detect snakes when the scene is perceptually complex and allows good camouflage for lurking snakes. These findings also extend previous results (Soares et al., 2009) suggesting that, even when the task places higher perceptual demands, snake distractor stimuli seem to be processed to a greater extent than the control conditions. In turn, this suggests that snake processing is fairly automatic, in the sense that it does not depend on general capacity limits. Snakes are undoubtedly more deadly threats than spiders and, consistent with an evolutionary origin, snakes remain a significant survival threat, with venomous snakes accounting for up to 94,000 human deaths worldwide per year (Kasturiratne et al., 2008). Furthermore, snakes remain the most frequent source of intense fear reported by humans (Agras et al., 1969), and fear of snakes is regularly observed among the old world primates (e.g., King, 1997; Mineka, Keir, and Price, 1980). Thus, fast and accurate detection of snakes amid a complex environment is clearly advantageous in terms of survival. This strongly reinforces the role of this evolutionarily-relevant stimulus in accessing the visual system, which is then consistent with the Snake Detection Theory proposed by Lynne Isbell (2006, 2009). The present study provides new insight into the study of fear and attention and suggests that snake stimuli may represent a valuable tool for studying such relationships.

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