

What Accounts for the Rapid Detection of Threat? Evidence for an Advantage in Perceptual and Behavioral Responding From Eye Movements

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Countless studies have reported that adults detect a variety of threatening stimuli more quickly than positive or neutral stimuli. Despite speculation about what factors drive this bias in detection, very few studies have examined the exact search strategies adults use to detect threatening stimuli in visual search. The current research uses an eye-tracker in a classic visual search paradigm in attempt to elucidate the factors that lead to rapid threat detection. Our results replicate previous work, demonstrating that adults detect threatening targets (snakes and spiders) more quickly and accurately than nonthreatening targets (flowers and mushrooms). Results from the eye-tracker extend these findings, suggesting that the bias for threat in detection tasks is driven by both an advantage in perception, or bottom up processing (faster fixations to threats vs. nonthreats), and an advantage in behavioral responding, or top down processing (faster behavioral responding to threats once a target is first fixated). Together, the results present a more complete picture of the mechanisms that drive rapid threat detection, suggesting that multiple factors can lead to an advantage for threat in visual search.

Keywords: threat detection, eye-tracking, visual search, snakes, spiders

Snakes and spiders are a very special category of stimuli for humans. They are the objects of two of our most common fears and phobias, and research suggests that we might be especially sensitive to their presence in visual attention (e.g., Öhman, Flykt, & Esteves, 2001). Aggressive or angry facial expressions fall into the same category, and attract our attention more readily than happy or neutral faces (Hansen & Hansen, 1988; Öhman, Lundqvist, & Esteves, 2001). What these stimuli have in common is that most adults consider them to be threatening. Research examining detection of threatening stimuli has shown consistently that adults and children detect snakes and spiders more quickly than a variety of benign stimuli like flowers, mushrooms, frogs, and cockroaches (LoBue, 2010a; LoBue & DeLoache, 2008; Öhman et al., 2001), and they detect angry faces more quickly than happy, neutral, or even sad faces (LoBue, 2009; Öhman, Lundqvist, & Esteves, 2001). This basic finding has been replicated using various stimuli (e.g., Tipples, Young, Quinlan, Broks, & Ellis, 2002), different paradigms (e.g., LoBue & DeLoache, 2008; Masataka, & Shibasaki, 2012), and across different species (e.g., Shibasaki, & Kawai, 2009), demonstrating that there is a clear attention (engagement) bias for threat in visual detection tasks.

Despite countless studies documenting the phenomenon, the mechanisms that drive rapid threat detection are still understudied.

Researchers have put forth several hypotheses. Öhman, Flykt, and Esteves (2001), for example, suggest that because snakes, spiders, and threatening conspecifics (i.e., human faces) signify evolutionarily relevant threats to human survival, our visual system may detect their presence very efficiently. To test this hypothesis, they presented adults with 2×2 and 3×3 matrices of threatening (snakes and spiders) and nonthreatening stimuli (flowers and mushrooms). In some of the matrices, all of the photographs were from the same category (e.g., nine photos of flowers), and in others, there was a single discrepant photograph (e.g., a single snake among eight flowers). Participants were told to press one button if all photos in the matrix were from the same category, and a second button if there was a discrepant photograph in the matrix. Results across experiments demonstrated that discrepant snakes and spiders were detected more quickly and more accurately than discrepant flowers and mushrooms. Further, detection of snakes and spiders was unaffected by the number of distracters present in each matrix—participants were equally fast at detecting the presence of these threatening stimuli regardless of whether there were three or eight distracters. This was not true for flowers and mushrooms—nonthreats were detected significantly faster in 2×2 than in 3×3 matrices.

Although Öhman and colleagues suggest that the *threatening message* produced by snakes and spiders is what causes adults to detect them so quickly, others have provided alternative accounts. Some have suggested that low-level perceptual features of the stimuli drive rapid threat detection. Indeed, several studies have shown that specific geometric shapes, such as the “V” shaped brow characteristic of angry faces or simple curvilinear figures common to snakes are sufficient in eliciting rapid detection in the absence of any threat-relevant cue (Larson, Aronoff, & Stearns, 2007; LoBue, 2013; LoBue & DeLoache, 2011; LoBue & Larson, 2010; see LoBue & Rakison, 2013, and Quinlan, 2013, for a review). Further, Becker, Anderson, Mortensen, Neufeld, and Neel (2011)

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reported that when controlling for many of the low-level perceptual differences between various threatening and nonthreatening faces, adults demonstrate a consistent bias for *positive* faces (i.e., happy faces) instead of threatening faces (i.e., angry faces). Thus, it is possible that low-level perceptual features common of threatening stimuli are responsible for eliciting rapid detection.

Other researchers argue that we do not have a bias to quickly detect threat at all; instead, we have difficulty *disengaging* from threat, and are slower to divert attention from threats than from nonthreats (Fox, Russo, Bowles, & Dutton, 2001). Thus, using threatening stimuli as distracters may draw attention away from nonthreatening targets. Several researchers have indeed reported that participants are slower to detect nonthreatening target stimuli when threatening stimuli are used as distracters (Byrne & Eysenck, 1995; Fenske & Eastwood, 2003; Forbes, Purkis, & Lipp, 2011; Gilboa-Schechtman, Foa, & Amir, 1999; Horstmann, Scharlau, & Ansorge, 2006; Lipp & Waters, 2007). However, other studies report an advantage for threatening stimuli when the distracters are uniformly benign across conditions (e.g., LoBue & DeLoache, 2011). Thus, the role of the distracter stimuli may not fully explain the phenomenon, and it remains unclear how difficulty disengaging from threatening distracters might contribute to an overall advantage for threat in detection.

More recent studies using eye-tracking technology have measured exact fixations in visual detection tasks in attempt to clarify how adults quickly detect threat. Reynolds et al. (2009), for example, examined visual fixations to positive and negative facial expressions and reported that participants' first fixations were quicker for negative faces than for positive faces. Further, Calvo, Avero, and Lundqvist (2006) reported that participants made fewer fixations before indicating that a discrepant angry face was present in a matrix than before indicating that a discrepant happy or sad face was present in a matrix. These findings suggest that there is indeed a bias for threat in perception.

In contrast, other studies using eye-tracking technology provide evidence against a perceptual bias for threat. Two studies report that the advantage for threat in spider phobic and socially anxious participants is driven by difficulty disengaging from the object of the participants' fear (spiders and angry faces respectively; Reinholdt-Dunn et al., 2012; Rinck, Reinecke, Ellwart, Heuer, & Becker, 2005). Derakshan and Koster (2010) also report no differences in latency to first fixate threatening versus nonthreatening stimuli. Similarly, Huijding, Mayer, Koster, and Muris (2011) found that in a change detection paradigm, adults with spider fear were actually *slower* to first fixate photographs of spiders than were nonfearful controls. Further, other studies report that the advantage for threat is due to faster *behavioral responding* (pressing a button) after threatening targets are first fixated. In other words, they suggest that threatening stimuli might evoke faster action, and not necessarily faster detection (Flykt, 2006; Flykt & Caldera, 2006).

So what drives rapid threat detection? With classic detection paradigms it is impossible to say for sure, as all assumptions about search strategy are based on average latency to make a behavioral response once a target is located. Although newer eye-tracking methodologies have the potential to allow for closer examination of what drives rapid threat detection, they have thus far provided mixed results—some reporting support for a bias in perception, others reporting difficulty disengaging from threat, and others still

reporting an advantage for threat in behavioral responding. Such inconsistencies might exist because of methodological differences between the studies, differences in the stimuli used, or because of a focus on anxious or phobic participants (Derakshan & Koster, 2010; Reinholdt-Dunne et al., 2012; Rinck et al., 2005). In the current investigation, we attempted to replicate a classic visual search study with typical adults using an eye-tracker. Adults were presented with 2×2 and 3×3 matrices of threatening (snakes and spiders) and nonthreatening stimuli (flowers and mushrooms). We used exactly the same stimuli and procedure as Öhman et al. (2001), asking participants to press one of two buttons to indicate whether all of the images in each matrix were from the same category, or whether there was a discrepant photograph present. The only exception is that besides measuring latency to press one of two buttons, we also measured latency to first fixate targets, as well as average time spent fixating each distracter.

There are several possible findings. First, it is possible that participant's first fixations will be faster for threatening targets than for nonthreatening targets. This finding would support a perceptual bias for threat. A second possibility is that the nature of the distracters drives rapid threat detection, and participants will have difficulty disengaging from threatening distracter stimuli when searching for nonthreatening targets (Fox, Russo, Bowles, & Dutton, 2001). If this is the case, we expect fixations for threatening distracters to be longer than fixations for nonthreatening distracters. A third and final possibility is that participants detect the location of threatening and nonthreatening targets equally fast, but behavioral responding (i.e., pressing a button once the target is detected) is more efficient for threat. If this is the case, latency to first fixate targets will be the same for threatening and nonthreatening stimuli, but latency to press a button on the keyboard once the target is first fixated will be shorter for threatening targets.

Method

Participants

Participants were 27 university students, 15 female and 12 male ($M = 20$ years; $R = 18 - 36$ year). All participants were recruited from the Rutgers University human subjects participant pool and received course credit for their participation. The Rutgers University Institutional Review Board approved all procedures and all participants signed an informed consent.

Materials

Again, we used exactly the same stimuli as Öhman et al. (2001). Photographs consisted of four different categories—snakes, spiders, mushrooms, and flowers—arranged in 3×3 and 2×2 matrices. Each picture was in full color, and measured 3.75 in. \times 6.0 in. Each matrix measured 11.25 in. \times 18.0 in. Each matrix contained either four or nine pictures from a single category (distracters), or three or eight pictures from one category (distracters) and a single discrepant picture from a second category (target). As in Öhman et al. (2001), discrepant threat-relevant targets (snakes and spiders) appeared with threat-irrelevant distracters (flowers and mushrooms) and vice versa, resulting in eight combinations of stimuli: snakes among flowers, snakes among mushrooms, spiders among flowers, spiders among mushrooms, flowers

among snakes, flowers among spiders, mushrooms among snakes, and mushrooms among spiders. Threat-relevant targets never appeared with threat-relevant distracters (e.g., snakes among spiders), and threat-irrelevant targets never appeared with threat-irrelevant distracters (e.g., flowers among mushrooms).

As in Öhman et al. (2001), for 3×3 matrices, the target appeared in all positions in the matrix except for the center space an equal number of times, resulting in 64 (8 possible positions \times 8 combinations of stimuli) matrices with one target and eight distracters. To balance the design, there was an additional 64 matrices with no targets (nine photos from a single category), for a grand total of 128 3×3 matrices. For 2×2 matrices, the targets again appeared in the four positions of the matrix an equal number of times, resulting in 32 (4 possible positions \times 8 combinations for stimuli) matrices with one target and three distracters, and an additional 32 matrices with no target (four photos from a single category), for a grand total of 64 2×2 matrices. As in Öhman et al. (2001), to match the number of 2×2 and 3×3 stimuli, the 64 2×2 matrices were presented twice, for a grand total of 128 2×2 matrices.

Apparatus

Eye-movements were recorded by a SensoriMotoric Instruments (SMI) iView X RED desk-mounted eye-tracker—an infrared, binocular system sampling at 120 Hz. A laptop running the iView software was used to present participants with the image displays described above on a 20-in. monitor with a 1680×1050 resolution. The eye-tracker was calibrated for each participant prior to the start of the experiment using a standard 4-point calibration procedure.

Procedure

Each participant was seated at a desk approximately 60 cm–80 cm in front of the 20-in. widescreen color monitor with a keyboard attached. At the beginning of each trial, a single matrix appeared in the center of the screen. Participants were instructed to respond as fast as possible by pressing “A” on the keyboard if all of the photos in the matrix were from the same category, and by pressing “L” if one of the photos was from a different category. After making their choice, they were instructed to press the space bar to advance to the next trial. Between each trial, an “X” appeared in the center of the screen in order to ensure that the participant’s focus was in the center for the start of each trial. Consistent with previous research, a visual fixation was defined as any single dwell time greater than 80 ms (Benedetto, Pedrotti, & Bridgeman, 2011; Patla & Vickers, 1997). Thus, each trial began after an 80 ms fixation to the “X,” and first fixations were defined as the first 80 ms dwell time after participants fixated the center of the screen. Participants responded to all 128 3×3 matrices and all 128 2×2 matrices in a random order. The iView software recorded each fixation and latency to press a button on the keyboard from the onset of each trial.

Snake and Spider Fear

After completing the detection task, each participant was asked to fill out the Snake Phobia Questionnaire (SNQ) to assess snake

fear, and the Spider Phobia Questionnaire (SPQ) to assess spider fear (Klorman, Weerts, Hastings, Melamed, & Lang, 1974). There were no significant correlations between the SNQ ($M = 9.8$) and any of the dependent measures for detection of snake targets, or the SPQ ($M = 10.9$) and the detection of spider targets (all $ps > 0.05$). Although at first glance this may seem surprising since Öhman et al. (2001) reported a relation between fear and detection, Öhman and colleagues compared the detection of individuals with very high snake and spider fear to a control group of very low-fear individuals. Further, others that have used the SNQ and SPQ to measure specific fear have treated a score of less than 21 as healthy, and nonphobic (e.g., Fessler et al., 2013). In the current study, no participants scored higher than a 21 on the SNQ and only two participants scored higher than a 21 on the SPQ. This indicates that our participants were in the normal range for snake and spider fear, and only a few qualified for a specific phobia. Thus, given that previous research examining detection of threat in fearful participants generally uses high fear or even clinical samples, is it not surprising that we found no relationship between fear and detection in our normative nonclinical sample of college students, and in fact, this finding is consistent with other research that also examined nonphobic participants (Waters, Lipp, & Randhawa, 2011).

Analyses

As in other standard visual search procedures, only trials in which participants responded correctly were used in the analyses. Errors were analyzed separately. In addition, there were 12 trials across participants where no behavioral response was given—participants simply tapped the keyboard to move on to the next trial without indicating whether all of the photographs in that trial were the same or whether there was a discrepant photo in the matrix. Such responses were rare ($< 0.3\%$ of the data) and these 12 trials were eliminated from all analyses.

As the eye-tracker produces several data points per participant per trial, Mixed Effects ANOVAs were used to analyze trial-level data with participant as a fixed variable. This type of model has several key advantages to traditional ANOVAs. The most important advantage is that it allows us to consider every data point in the analyses instead of using a single mean for every participant. By using every data point, Mixed Models take into account individual differences in a participants’ behavior over the course of many trials, reducing the potential for error (Baayen, Davidson, & Bates, 2008; Bagella, Sloan, & Heitjan, 2000; Gueorguieva & Krystal, 2004).

Results

Replication of Previous Findings

Before examining what drives adults’ rapid detection of threat, it was important to examine whether we were able to replicate the basic advantage for threat reported in Öhman et al. (2001). First we examined target present matrices. In a 2 (Target Type: threatening vs. nonthreatening) \times 2 (Matrix Size: four or nine photos) Mixed Effects ANOVA on latency to make a behavioral response, there was a main effect of target type, $F(1, 3055) = 7.9, p = .005$, a main effect of matrix size, $F(1, 3055) = 6.8, p = .009$, and a target

type by matrix size interaction, $F(1, 3055) = 3.7, p = .054$. Replicating the results of previous work, participants detected threatening targets ($m = 1,461$ ms) more quickly than nonthreatening targets ($m = 1,549$ ms), and they detected targets in 2×2 matrices ($m = 1,465$ ms) more quickly than targets in 3×3 matrices ($m = 1,548$ ms). The interaction indicated that the effect of matrix size was only significant for nonthreatening targets, $F(1, 1519) = 8.1, p = .005$, and not for threatening targets, $F(1, 1536) = 0.3, p = .575$. In other words, when detecting nonthreatening targets, participants were significantly faster with 2×2 matrices ($m = 1,479.1$ ms) than with 3×3 matrices ($m = 1,625$ ms). Conversely, when detecting threatening targets, participants were equally fast with both 2×2 ($m = 1,451$ ms) and 3×3 matrices ($m = 1,473$ ms; see Figure 1). Further, the advantage for threatening stimuli was only significant for 3×3 matrices, $F(1, 1468) = 8.3, p = .004$; it was not significant for 2×2 matrices, $F(1, 1587) = 0.56, p = .455$, suggesting that the advantage for threat was only evident with higher numbers of competing stimuli.

Next, we examined target-absent matrices (i.e., matrices with four or nine distracters). In a second 2 (Distracter Type: threatening vs. nonthreatening) \times 2 (Matrix Size: four or nine photos) Mixed Effects ANOVA on latency to make a behavioral response, there was a marginal main effect of distracter type, $F(1, 3320) = 3.3, p = .071$, a significant main effect of matrix size, $F(1, 3320) = 22.9, p < .000$, and a marginally significant distracter type by matrix size interaction, $F(1, 3320) = 3.5, p = .061$. Participants responded marginally more quickly to matrices made up of threatening distracters ($m = 1,512$ ms) than to matrices made up of nonthreatening distracters ($m = 1,581$ ms). They also responded more quickly to 2×2 matrices ($m = 1,445$ ms) than to 3×3 matrices ($m = 1,637$ ms). Unlike our results with target-present matrices, the marginal interaction indicates that the effect of matrix size was slightly stronger for threatening distracters, $F(1, 1660) = 38.4, p < .000$ ($2 \times 2, m = 1,372$ ms; $3 \times 3, m = 1,638$

ms), than for nonthreatening distracters, $F(1, 1660) = 3.0, p = .085$, ($2 \times 2, m = 1,519$ ms; $3 \times 3, m = 1,636$ ms).

Finally, we analyzed the number of errors participants made in both target present and target absent trials. In a 2 (Distracter Type: threatening vs. nonthreatening) \times 2 (Matrix Size: four or nine photos) Mixed Effects ANOVA on the number of errors made across target absent trials, there were no significant results (8% trials). In a second 2 (Target Type: threatening vs. nonthreatening) \times 2 (Matrix Size: four or nine photos) Mixed Effects ANOVA on target present trials, there was a main effect of target type, $F(1, 3346) = 14.7, p < .000$, a main effect of matrix size, $F(1, 2246) = 26.2, p < .000$, and a target type by matrix size interaction, $F(1, 3346) = 9.5, p = .002$. Not surprisingly, participants made more errors on 3×3 matrices (11% of trials) than on 2×2 matrices (6% of trials). Further, for trials with nonthreatening targets participants erred on 10% of the trials; they were significantly more accurate for trials with threatening targets, only erring in 7% of the trials. The interaction indicates that again the effect of matrix size was only significant for nonthreatening targets, $F(1, 1698) = 28.8, p < .000$ ($2 \times 2 = 7\%$; $3 \times 3 = 14\%$); there was no significant difference in the number of errors made for threatening targets, $F(1, 1787) = 1.7, p = .196$ ($2 \times 2 = 6\%$; $3 \times 3 = 8\%$).

Together, these findings replicate the results of Öhman et al. (2001), suggesting that threatening targets are detected more quickly and more accurately than nonthreatening targets in 3×3 matrices, and that the detection of threatening targets is not affected by increasing the number of distracters in each matrix. However, these findings alone do not provide information about what drives participants' rapid responses to threatening stimuli. Next, we use fixation data to determine what drives these results.

Target Fixations

Although the analyses described above indicate that participants more rapidly pressed a button on the keyboard after detecting threatening versus nonthreatening targets, these data do not tell us whether participants fixated threatening stimuli more quickly than nonthreatening stimuli, or whether they were simply faster to press a button once a threatening target was detected. Thus, here we analyzed participants' first fixation to each discrepant photograph in target-present matrices to examine whether adults were indeed faster to fixate threatening versus nonthreatening stimuli.

In a 2 (Target Type: threatening vs. nonthreatening) \times 2 (Matrix Size: four or nine photos) Mixed Effects ANOVA on latency to first fixate each target stimulus in target present matrices, there was a main effect of matrix size, $F(1, 2373) = 18.1, p < .000$, and a target type by matrix size interaction, $F(1, 2373) = 10.1, p = .001$, but no significant main effect of target type, $F(1, 2373) = 0.7, p = .395$. Not surprisingly, participants were quicker to first fixate targets in 2×2 ($m = 754$ ms) than in 3×3 matrices ($m = 832$ ms). They were also slightly faster to first fixate threatening targets ($m = 785$ ms) than nonthreatening targets ($m = 799$ ms), but this difference was not statistically significant. The interaction indicates that while there was no significant difference in first fixations to threatening versus nonthreatening targets in 2×2 matrices, $F(1, 1215) = 2.7, p = .098$ (nonthreatening, $m = 733$ ms; threatening, $m = 775$ ms), there was a significant difference in first fixations to threatening versus nonthreatening targets in 3×3

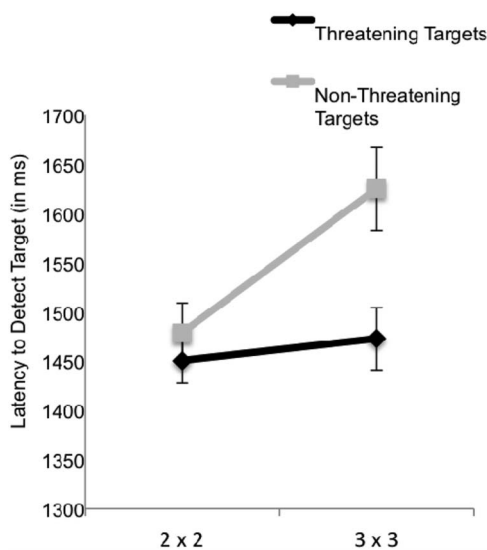


Figure 1. Average latency to detect threatening and nonthreatening targets in target-present matrices, from the start of the trial to a behavioral response. These results replicate those of Öhman et al. (2001).

3 matrices, $F(1, 1158) = 8.1, p = .005$, with participants first fixating threatening targets ($m = 795$ ms) significantly faster than nonthreatening targets ($m = 867$ ms; see Figure 2).

It is important to note that target stimuli were fixated at least once in only 78% of trials (only these trials are included in the analysis above). Surprisingly, in the remaining 22% of target-present trials ($n = 683$), the target was never fixated, but participants still made a correct response. There were an additional 102 target-present trials in which a target was never fixated and participants erroneously indicated that no target was present. Consistent with the results presented above, participants were more likely to make a correct behavioral response without fixating the target when the targets were threatening ($n = 379$ trials) than when the targets were nonthreatening ($n = 304$), $F(1, 3057) = 9.7, p = .002$.

The Role of the Distracter Stimuli

Another question is whether participants scan nonthreatening distracters more quickly than threatening distracters. Indeed, several researchers have suggested that a key factor in driving rapid threat detection is difficulty disengaging from threatening stimuli. Thus, when threatening stimuli are used as the distracters, they might slow down the detection of nonthreatening targets. To address this issue, we examined the average amount of time participants spent fixating each distracter before first fixating the target. In a 2 (Target Type: threatening vs. nonthreatening) \times 2 (Matrix Size: four or nine photos) Mixed Effects ANOVA, there were no significant main effects of target type, $F(1, 1529) = 0.1, p = .821$, or matrix size, $F(1, 1529) = 0.0, p = .981$, and no interaction, $F(1, 1529) = 2.2, p = .142$. Thus, for target-present matrices, participants fixated distracters for the same amount of time regardless of threat-relevance.

The same question was addressed in target-absent matrices, where we analyzed how long participants fixated each photograph before deciding that no target was present. In a 2 (Distracter Type:

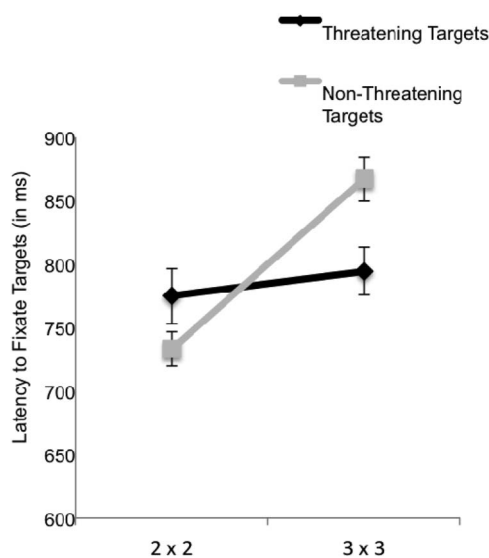


Figure 2. Average latency to first fixation of threatening and nonthreatening targets.

threatening vs. nonthreatening) \times 2 (Matrix Size: four or nine photos) Mixed Effects ANOVA, there was a main effect of matrix size, $F(1, 3269) = 252.4, p < .000$, and a marginally significant distracter type by matrix size interaction, $F(1, 3269) = 3.6, p = .059$; there was no significant main effect of distracter type, $F(1, 3269) = 0.1, p = .723$. Participants scanned each photograph more quickly in 3 \times 3 ($m = 265$ ms) than in 2 \times 2 matrices ($m = 426$ ms). The interaction indicates that there was no difference in time spent fixating each photograph in 2 \times 2 matrices, $F(1, 1529) = 1.4, p = .236$, but the effect was approaching significance for 3 \times 3 matrices, $F(1, 1740) = 3.2, p = .076$, indicating that in larger matrices, participants scanned photographs slightly faster when they were threatening ($m = 273$ ms).

Together these data present only very weak evidence that participants spent more time fixating nonthreatening stimuli than threatening stimuli in target-absent matrices. However, no such results were evident in target-present matrices, suggesting that threatening distracter stimuli do not necessarily detract from the detection of nonthreatening targets, and vice versa—participants spent an equal amount of time fixating each distracter stimulus before reaching targets, regardless of threat-relevance.

Behavioral Responding

A final possibility that has been suggested in the literature is that adults are not necessarily faster to fixate threatening versus nonthreatening stimuli; instead, they are faster to make a behavioral response once a threatening target has been identified. To address this issue, we asked how fast participants made a behavioral response on the keyboard after first fixating the target in each trial. In a 2 (Target Type: threatening vs. nonthreatening) \times 2 (Matrix Size: four or nine photos) Mixed Effects ANOVA, there was only a main effect of target type, $F(1, 2373) = 5.1, p = .024$; there was no effect of matrix size, $F(1, 2373) = 0.0, p = .975$, and no interaction, $F(1, 2387) = 0.1, p = .745$. Participants were indeed faster to make a behavioral response after first fixating threatening targets ($m = 748$ ms) than after first fixating nonthreatening targets ($m = 826$ ms; see Figure 3).

Discussion

The current investigation was aimed at exploring what drives adults' rapid detection of threatening stimuli in visual search studies. The results replicate previous work, demonstrating that adults detect threatening stimuli like snakes and spiders more quickly and accurately than nonthreatening stimuli like flowers and mushrooms in larger matrices. Further, detection of threatening targets was equally fast and accurate regardless of the number of distracters present in each matrix. This was not true for nonthreatening targets, which took longer to detect (and were detected less accurately) as the number of distracters increased. Together, these results replicate those reported in Öhman et al.'s (2001).

Besides replicating previous research, the current investigation takes this work a step further by using eye-tracking technology to examine the factors that contribute to the advantage for threat in visual search. There are several important findings. First, participants first fixated threatening targets more quickly than nonthreatening targets in 3 \times 3 matrices. It is important to note that this

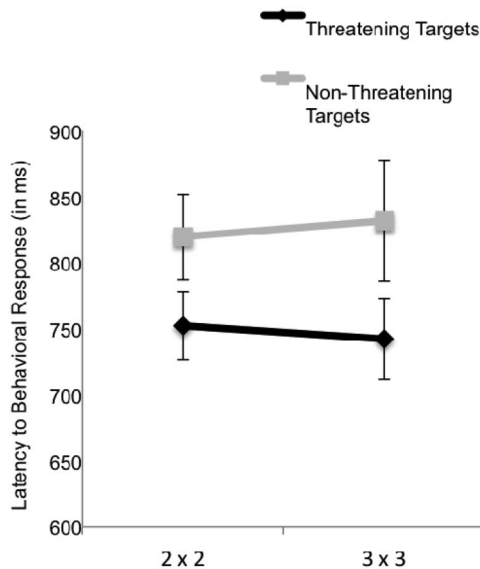


Figure 3. Average latency from first fixation to behavioral response for threatening and nonthreatening targets.

result was only evident in larger matrices, suggesting that in smaller matrices, floor effects might be present. In other words, detection of targets in 2×2 matrices might happen so rapidly that variability across conditions cannot be detected. These findings suggest that the advantage for threat in visual search tasks cannot solely be accounted for by the role of the distracter stimuli, or by more rapid behavioral responding once a threat is detected: They instead demonstrate that there is indeed an advantage for threat in perception.

Second, participants not only fixated threatening stimuli more quickly than nonthreatening stimuli, they were also faster to make a behavioral response once a threatening target was detected. This replicates previous findings with anxious or phobic participants also using eye-tracking technology (Derakshan & Koster, 2010). It suggests that besides perceptual or bottom-up factors driving rapid threat detection, there might be top-down, or cognitive factors driving detection of threat as well. Indeed, several researchers have studied the role of cognition in threat detection and have shown that both adults and children can *learn* to quickly detect threatening stimuli through negative experiences, such learning to pair a neutral stimulus with a mild electric shock, or by hearing negative verbal information (Field, 2006a, 2006b; Koster, Crombez, Van Damme, Verschuere, & De Houwer, 2004; LoBue, 2010b; Milders, Arash, Logan, & Donnellon, 2006; Purkis & Lipp, 2009). Thus, in combination with the fixation results, findings from behavioral responses suggest that both perceptual (bottom-up) and cognitive (top-down) components might both be involved in rapid threat detection.

It is interesting that participants were able to make accurate behavioral responses without ever fixating the target. This suggests that participants used peripheral vision in a portion of trials to locate targets. One possible explanation for this finding is that low-level stimulus differences between the stimuli allowed for some of the stimuli to be detected peripherally. Researchers have generally asserted that the findings reported here and in previous

research are due to the threatening message that can be gleaned from the stimuli. An alternative explanation for this work, however, is that low-level perceptual differences between the threatening and nonthreatening stimuli drive detection results. As mentioned above, several studies have shown that specific geometric shapes, such as the “V” shaped brow characteristic of angry faces or simple curvilinear figures common to snakes are sufficient in eliciting rapid detection in the absence of any threat-relevant cue (Larson, Aronoff, & Stearns, 2007; LoBue, 2013; LoBue & DeLoache, 2011; LoBue & Larson, 2010). Thus, despite building evidence for a bias for threat in perception, these findings suggest that such a bias may not necessarily be due to the threatening nature of the stimuli.

Although these findings are consistent with much of the previous literature, there are other studies that have reported inconsistent findings with those presented here. As mentioned above, some studies report no differences in latency to first fixate threatening versus nonthreatening stimuli (Derakshan & Koster, 2010). Others report an advantage in detection for *positive* stimuli instead of threatening or negative stimuli (Becker, Anderson, Mortensen, Neufeld, & Neel, 2011). Further, although several studies report that the advantage for threat lies in difficulty disengaging from threatening distracters, there was very little evidence here that participants had difficulty disengaging from threatening distracters when searching for nonthreatening targets. There was no difference in the amount of time participants spent fixating threatening versus nonthreatening distracters in target-present matrices. Further, although a slight trend in this direction was found for target-absent matrices, it was only approaching statistical significance. It is possible that difficulty disengaging from threatening stimuli is only evident in anxious or phobic participants. Indeed, much of the research reporting results of this nature come from work with clinical populations (e.g., Reinholdt-Dunne et al., 2012; Rinck, Reinecke, Ellwart, Heuer, & Becker, 2005). Further, many of the inconsistent results from previous literature might also be due to methodological differences across studies; several paradigms have been used to measure sensitivity to threat, including visual search paradigms, dot-probe, change detection paradigms, and emotional Stroop tasks to name a few. Future research comparing search strategies for threat in clinical and nonclinical populations using more than one paradigm might help elucidate why some of these inconsistencies across studies have been reported.

Despite the strengths of using a well-known paradigm and stimulus set such as that of Öhman et al. (2001), there are also limitations to this type of work. Namely, any problems with Öhman et al.’s stimuli might have been carried over into the current study. One potential issue is that the stimuli were in color, which might have caused some photographs to stand out more than others. Another potential issue is that a uniform set of distracter stimuli was not used; in other words, snake and spider stimuli served as both targets and as the distracters for flower and mushroom targets. A third, and perhaps very important problem is that the nonthreatening stimuli used here were not animals. Past research has shown that photographs of *any* animal can be detected more quickly than photographs of flowers and mushrooms (Lipp, 2006; Lipp, Derakshan, Waters, & Logies, 2004; Tipples et al., 2002). Recent work has controlled for these issues by using black and white images, or by using a uniform set of distracter stimuli that are also animals (e.g., LoBue, 2010a; LoBue & DeLoache,

2008, 2011), but many visual search studies still suffer from similar problems with control stimuli (for a review, see Quinlan, 2013). Although some of the recent work employing more tightly controlled stimuli has still produced an advantage for snakes and spiders over other animals such as frogs and cockroaches, future research examining fixations to a more tightly controlled stimulus set can help us further examine the underlying processes that make threatening stimuli so salient in visual search paradigms.

Together, the results of the current research suggest that threats are privileged in visual detection tasks for multiple reasons, and an advantage in one single domain cannot necessarily explain the results reported in previous work. We found an advantage both in first fixating threatening targets and in making a behavioral response to indicate that a threat was detected, suggesting that both perceptual, or bottom-up factors play a role in rapid threat detection, and cognitive, or top-down factors play a role in detection as well. Thus, instead of one single factor accounting for the advantage for threat across visual search studies, a more parsimonious explanation for the inconsistencies found in previous research is that visual detection is a complex task that involves the interaction of a variety of factors (Frischen, Eastwood, & Smilek, 2008; LoBue, 2013). Recent studies echo these findings, suggesting that perceptual, cognitive, and emotional factors can all play a role in driving rapid threat detection (Field, 2006a, 2006b; LoBue, 2013; Rutherford, MacLeod, & Campbell, 2004). Thus, perhaps rapid threat detection is best conceptualized as a continuum of search efficiency that can be driven by a variety of individual and interacting factors (Horstmann & Becker, 2008).

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