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Scorpion Detection in Humans: An Initial Investigation

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ABSTRACT

Previous research suggests humans possess psychological adaptations to minimize contact with ancestrally threatening animals, including the rapid detection of some key predators. While the visual prioritization of snakes, spiders, and lions has been well-studied, similar work has not yet been conducted for scorpions. Yet, these dangerous arthropods have likely also been a recurrent survival threat for our species. Scorpions have an extensive and long evolutionary history with mammals, are widely distributed geographically, and the stings from some species can be lethal. Moreover, recent studies show that scorpions elicit high levels of fear and disgust. Thus, humans may also possess psychological adaptations for the rapid detection of these creatures. Here, we tested this hypothesis in a sample of 35 college students in the northeastern United States using a standard target-discrimination task with images of scorpions and grasshoppers (a non-threatening control stimulus). Contrary to our predictions, we show that the average latency to detect scorpions and grasshoppers did not vary significantly across trials ($p > 0.05$). However, scorpions did elicit significantly more fixations when they were included as distractor stimuli ($p = 0.01$). Overall, these results provide mixed support for the visual prioritization of scorpions.

KEYWORDS

Eye-Tracking, Prepared Fear, Threat Detection, Vigilance, Visual Search

INTRODUCTION

Biologists have long recognized that predator-prey interactions drive the evolution of many functional (i.e., adaptive) traits across the animal kingdom, whereby there is a coevolution of traits that enhance foraging among predators and those that aid in survival among prey (Schmitz, 2017). Antipredator adaptations in prey species include, among others, the ability to recognize and rapidly detect predators (Isbell,

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2006) as well as evasive and escape behaviors induced by changes in neurophysiology (Wingfield et al., 1998; Sherriff & Thaler, 2014). Given that predation threats have been a consistent selective pressure during human evolutionary history (Hart & Sussman, 2005; 2011), it stands to reason that we have evolved psychological adaptations to avoid contact with ancestrally dangerous animals.

Consistent with this view, Seligman (1971) first proposed that humans may be biologically prepared to learn certain objects and situations that posed a survival risk during human evolution. This framework, known as Preparedness Theory, was initially formulated based on the selective nature of stimuli that elicit phobias, i.e., those that hold evolutionary significance (e.g., snakes, heights). This theory has had a large and lasting impact on the field of psychology (McNally, 2016), and is supported by a range of studies showing that fear-relevant stimuli are easily learned and more resistant to extinction in conditioning trials (e.g., McNally, 1987). Moreover, research programs stemming from Seligman's work have provided support for the existence of evolved fear modules via fear elicitation and fear learning (Öhman & Mineka, 2001; Mineka & Öhman, 2003), with snakes serving as a prototypical stimulus (Öhman & Mineka, 2003).

Snakes have been a recurrent survival threat throughout mammalian evolution (Hsiang et al., 2015), and Isbell (2006) proposed that the threat posed from venomous snakes has a been a driving force on the evolution of the primate visual system, i.e., Snake Detection Theory. While there is good evidence that a specific fear of snakes is developed through learning (Mineka et al., 1984), psychological and neurological studies on adults and children alike indicate that we possess specialized adaptations for the rapid detection of these dangerous animals (e.g., Gallup & Meyers, 2021; Lobue & DeLoache, 2008; Masataka, Hayakawa, & Kawai, 2010; Soares, Lindström, Esteves, & Öhman, 2014; Öhman, Flykt, & Esteves, 2001; Van Strien, & Isbell, 2017). Notably, developmental studies with infants suggest that we are born with a perceptual template for detecting these distinctive predators (Lobue & DeLoache, 2010; Bertels et al., 2020). In addition, research measuring event-related potentials has revealed that snake stimuli elicit greater neurological activation compared to matched control stimuli (Van Strien, Franken, & Huijding, 2014; Van Strien, Christiaans, Franken, & Huijding, 2016; Van Strien & Isbell, 2017).

Spiders have also been widely viewed as recurrent survival threats to humans, spurring similar lines of research examining our perceptual and emotional responses to these animals (e.g., Gerdes, Uhl, & Alpers, 2009; New & German, 2015; Rakison & Derringer, 2008). Like snakes, the risk posed by spiders comes from the fact that some species are lethally venomous (Nentwig & Kuhn-Nentwig, 2012). Thus, as expected, studies of visual search have provided support for a visual prioritization of spider stimuli (e.g., Lobue, 2010; Rinck et al., 2005). In general, however, detection and imaging studies on primates tend to reveal a much more robust and reliable response to snakes than spiders (e.g., He, Kubo, & Kawai, 2014; Shibasaki & Kawai, 2011; Van Strien, Christiaans, Franken, & Huijding, 2014), with some studies finding no support for the rapid detection of these arachnids (Kawai & Koda, 2016).

Although snakes and spiders have received a disparate focus in the literature, large-bodied felids have also been a recurrent predation threat during human evolution (Coss et al., 2009; Hart & Sussman, 2005; Treves & Naughton-Treves, 1999). Even within the past century, records reveal that over 14,000 humans have been killed by tigers, leopards, lions, and pumas (Löe, J., & Röskaft, 2004). In one study examining the visual prioritization of lions, it was found that these large carnivores captured the attention of participants in a highly similar manner to snakes when presented in search tasks (Yorzinski, Penkunas, Platt & Coss, 2014). In addition, people were faster at detecting, and were more distracted by, lions compared to non-threatening prey animals (i.e., impala) – a finding that was recently replicated by an independent laboratory using the same stimuli (Gallup and Wozny, in press). Moreover, imagery depicting forward-facing lions tend to garner the most attention (Yorzinski, Tovar, & Coss, 2018), presumably due to the perceived threat and level of risk posed by animals assuming this orientation. Notably, however, a more recent study found that when comparing lions and impalas with an upright posture, no differences emerged in terms of detection latency (Yorzinski & Coss, 2020). Thus, like spiders, there is mixed support for the rapid detection of lions.

Still other predators have likely been recurrent survival threats during human evolutionary history. In particular, scorpions possess many analogous characteristics as venomous predators when compared to snakes and spiders, and thus serve as a good candidate for the further exploration of evolved threat detection mechanisms. Scorpions are ancient (dating back 450mya), widely distributed across the world, morphologically unique, and their stings can be fatal (Lourenco, 2018). Even today, scorpions pose a significant survival threat to humans with reports indicating that 1.5 million people are stung by scorpions each year, resulting in roughly 2600 mortalities (Chippaux, 2012). These data suggest that fatalities from envenomizations from scorpion stings are less common than snake bites, which kill roughly 100,000-125,000 people each year (Cheng & Currie, 2004; Perry, Lacy, & Das, 2020), but considerably more frequent than those resulting from spider bites, which are extremely rare (< 0.001 per million; Nentwig & Kuhn-Nentwig, 2012). Yet, only a few studies have examined how humans respond to scorpions.

Among the studies that have been conducted, scorpions appear to elicit high levels of fear and disgust (Frynta et al., 2021; 2023). Findings from the United States and Malaysia suggest that scorpions are feared by people more than spiders, and this is true even among populations with limited to no exposure to these animals, i.e., individuals residing in cold climates (Vetter et al., 2018; Azil, Yakub, Hassan, & Sharip, 2021). Similarly, one study conducted in Somalia, which the authors note is within an environment and region akin to where humans evolved, found that snakes and scorpions were in fact the most feared animals (Fyrnta et al., 2023).

The spider-scorpion generalization hypothesis proposes that fear of spiders might have originated from a more generalized fear of scorpions (Frynta et al., 2021). In support of this view, chelicerates, of which both spiders and scorpions belong, are perceived as one distinct group and scorpions represent the only truly dangerous taxon. To further test this hypothesis, Rudolfová et al. (2022) conducted a cross-cultural study employing a gaze preference paradigm, whereby images were paired side-by-side, to assess whether scorpions garnered more attention than spiders and grasshoppers (a control stimulus). Results from this work showed a significant attentional bias towards scorpions as measured by both fixation frequency and total fixation duration (Rudolfová et al., 2022). Therefore, there is growing evidence to suggest humans may have initially evolved specialized mechanisms to detect and avoid scorpions, and that this has extended to spiders (Frynta et al., 2021).

Given this backdrop, the current study investigated, for the first time, whether humans rapidly detect scorpions when presented in visual search tasks. Using a repeated measures design, an image-discrimination task was employed that included images of scorpions and grasshoppers, and eye-tracking was used to measure both detection latency and distractor fixation frequency across trials. Given that the activation of circuits associated with fear modules may require prior learning and experience (Mineka et al., 1984), participants were asked to indicate whether they had ever had real-life exposure to scorpions outside of viewing these animals in enclosures within captivity, and whether they had ever been stung by a scorpion in the past. However, it was hypothesized that, like snakes, scorpion images would be detected more rapidly and garner greater distractor fixations across trials independent of prior experience with these dangerous animals.

METHOD

Participants

A total of 35 college students (15 female, $M \pm$ SD age: 20.4 $\pm$ 2.72) participated in this study during the 2022-2023 academic year. Recruitment occurred through the psychology pool at a public research university in the northeastern United States, and the sample size was determined by the total recruitment across one academic term (15-week period). Overall, the number of participants was comparable to previous studies in this literature (Lobue et al., 2008; Öhman et al., 2001) and a post-hoc power analysis using G*Power 3.1 indicated power of 0.82 to detect a medium effect (Cohen's d = 0.5). This effect size was viewed as conservative based on similar studies using snakes, spiders, and lions, which typically find large main effects of target stimulus (e.g., Lobue, 2010; Yorzinski et al., 2014; Gallup & Meyers, 2021). The study was approved by the local Institutional Review Board (#2022-4), and each student was awarded course credit for their participation in the study.

Design

The study design matched Yorzinski et al. (2014), but in this case the stimuli consisted of 24 images of scorpions and 24 images of grasshoppers that were acquired from internet searches. The images depicted animals primarily from a side-view (though some were partially forward-facing), and the background varied. Most of the images were from a natural habitat, while others appeared to be in captivity. All stimuli are available upon request from the corresponding author. Grasshoppers were chosen as a non-threatening control stimulus based on previous research by Rudolfová et al. (2022), which directly compared the visual attention (as measured by fixation frequency and duration) towards scorpions and grasshoppers using a gaze preference paradigm. Grasshoppers are comparable in morphology to scorpions, but differ markedly in threat and fear elicitation (Frynta et al., 2021).

To assess how the pure stimulus characteristics of these stimuli altered visual attention, all images were transferred to grayscale, which is common in the literature

(Gallup & Meyers, 2021) and does not impact the detection of threatening stimuli (Flykt, 2005; Hayakawa, Kawai, and Masataka, 2011; Yorzinski et al., 2014). The resulting images were then used to create a total of 48 matrices (24 scorpion-target and 24 grasshopper-target). Each matrix consisted of a 3 x 3 array with a single target image among seven distractors, and the middle position was left blank. Methods for randomizing the image locations followed Yorzinski et al. (2014), and thus participants were not able to predict where the target image would appear during trials. Each matrix was 1,781 x 945 pixels (49 x 26 cm) and positioned in the center of a stimulus presentation monitor (EIZO FlexScan EV2451) with a total resolution of 1,920 x 1,080 pixels (52.8 x 29.7 cm). Images within each matrix were 288 x 219 pixels (7.92 x 6.01 cm).

Procedure

Participants were seated at a desk approximately 65 cm from a Tobii Pro Spectrum 150 Hz eye-tracker attached to the stimulus presentation monitor, and a researcher seated behind a partition provided verbal instructions during testing. Each trial was initiated by a focal point positioned in the center of the presentation monitor for 1,000 ms, and this was followed by a search matrix that appeared for 3,000 ms and then a blank screen for 1,000 ms (Figure 1). Prior to initiating each block of trials, participants were instructed to search for and focus their attention on the single target image (scorpion or grasshopper) among the seven distractors within each array as quickly as possible (Figure 2), and to maintain their focus on this image until the next trial began. Eight practice trials were administered beforehand, each consisting of a frog target with flower distractors, and verbal feedback from the researcher was provided to ensure the participants understood the task.

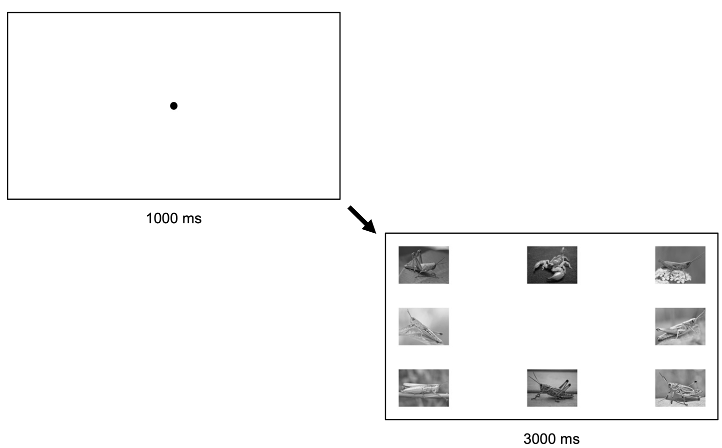

Figure 1. *Depiction of the focal point and stimulus presentation for one of the scorpion-target matrices.*

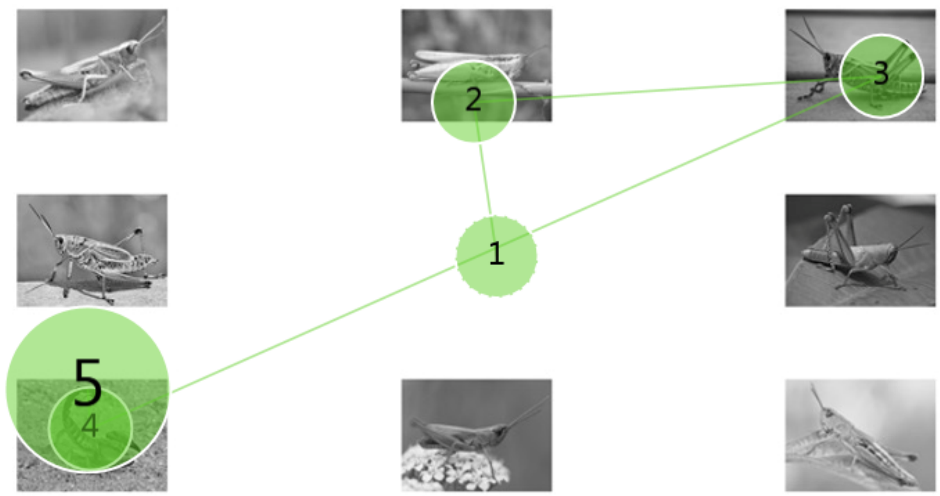

Figure 2. *Example search during a scorpion-target trial, in which a participant fixated on two grasshopper distractors prior to locating and holding their attention on the target scorpion. The numbers identify the sequence of fixations, beginning at the focal position.*

The experiment began following instructions for the first block of trials, which matched the instructions from the practice trials but now included reference to scorpions and grasshoppers. The researcher then initiated the display of 24 consecutive scorpion- or grasshopper-target matrices and remained silent during testing. After competition of the first block, new instructions were provided for the second block and the remaining 24 matrices were displayed. The presentation order (scorpion-target -> grasshopper-target; grasshopper-target -> scorpion-target) was counterbalanced and assigned in rotating order across participants. After participants completed the second block, a short questionnaire was provided to obtain demographic information and the participants' previous experience with scorpions.

Analysis

A predefined area of interest was drawn over each target image across all 48 matrices (overlapping the edges by approximately 67 pixels, or 1.83 cm), and this was used to capture the latency in ms to fixate on the target images across the trials. Fixations on distractor stimuli were coded manually using the visual displays produced from each trial in Tobii Pro Lab. Planned paired *t*-tests were run to compare (1) the mean latency in ms to fixate on the scorpion and grasshopper targets and (2) the mean number of distractor images that were fixated on across trails. All statistics were performed in Jamovi (The Jamovi Project, 2021), and the data sets used to generate these results have been uploaded to the Harvard Dataverse repository (https://doi.org/10.7910/DVN/OPKRJQ).

RESULTS

The descriptive statistics for fixation latency and distractor fixation frequency can be found in Table 1. Overall, there was no difference in the average latency to detect scorpions compared to grasshoppers (-11ms) (t_{34} = 0.429, p = 0.670, Cohen's d = 0.073; Figure 3). However, scorpions did elicit significantly more distractor fixations across trials (+0.22) (t_{34} = 2.630, p = 0.010, Cohen's d = 0.445; Figure 4).

Table 1. *Descriptive statistics for the eye-tracking measures*

	Grasshopper-Target Searches	Scorpion-Target Searches
Detection Latency	1048 ± 176	1037 ± 144
Distractor Fixations	3.61 ± 0.707	3.39 ± 0.645

Note: data are presented in Means ± Standard Deviations

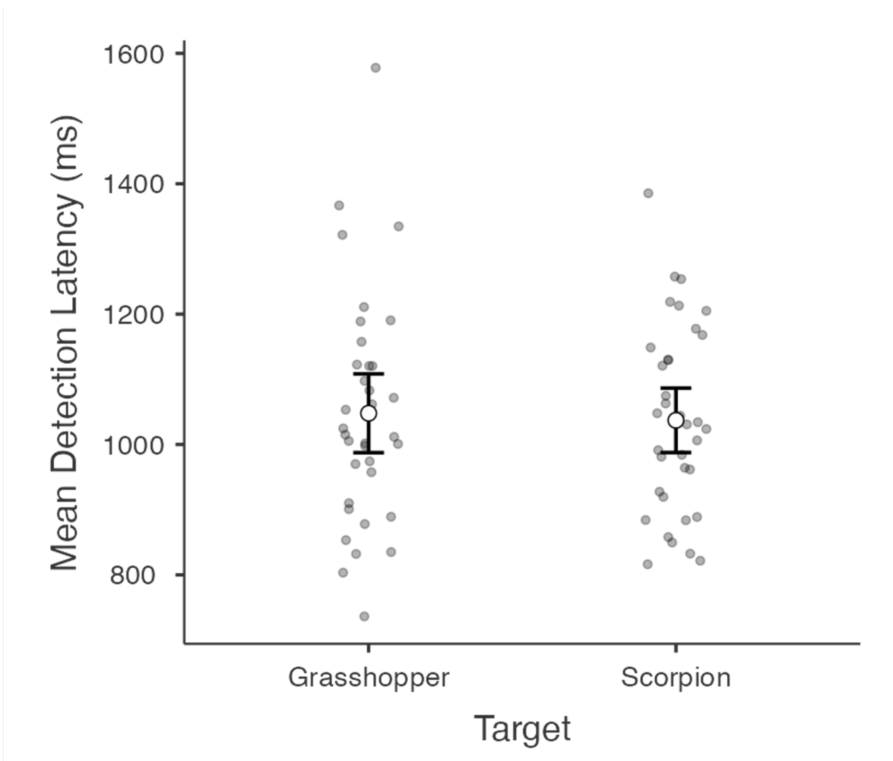

Figure 3. *There was no significant difference in the detection latencies across the scorpion-target and grasshopper-target search trials. Data are presented as estimated marginal means + 95% confidence intervals, with observed mean scores displayed for each participant.*

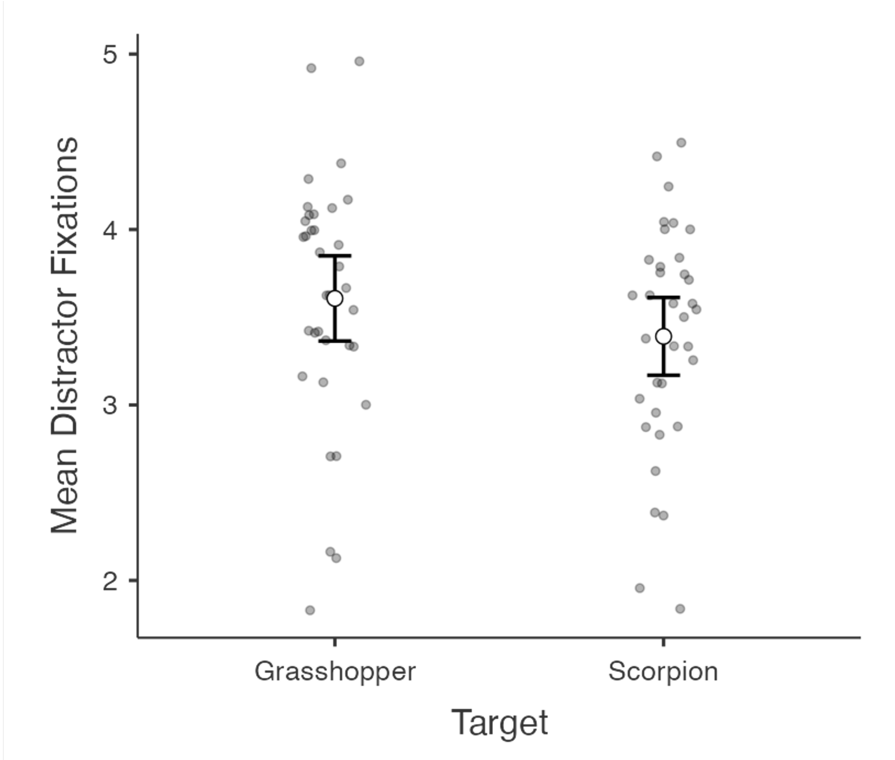

Figure 4. *The number of distractor fixations was significantly higher during the grasshopper-target searches, indicating that scorpions were more distracting than grasshoppers. Data are presented as estimated marginal means + 95% confidence intervals, with observed mean scores displayed for each participant.*

As expected from the northeastern US sample, only four participants (11.4%) reported ever seeing a scorpion in real-life (outside of an enclosure or zoo, etc.). Notably, one individual indicated being stung by a scorpion in the past. However, the overall findings do not change when parceling out participants that have encountered scorpions in nature (detection latency: t_{30} = 0.234, p = 0.817, Cohen's d = 0.042; distractor fixations: t_{30} = 2.570, p = 0.015, Cohen's d = 0.461).

DISCUSSION

Only recently has research begun to explore whether humans possess psychological adaptations to minimize contact with scorpions (Frynta et al., 2021; 2023). Likely due to the threat these animals pose with their venomous stings, scorpions elicit high levels of fear and disgust among people across divergent geographic locations and cultural settings (Frynta et al., 2021; Vetter et al., 2018; Azil et al., 2021). While one study found that people tend to fixate longer on scorpions when presented as focal stimuli in a gaze preference paradigm (Rudolfová et al., 2022), which also used grasshoppers as a comparison control stimulus, thus far there have been no attempts to examine whether humans show a rapid detection of these dangerous animals when presented in unpredictable locations.

The results from the current study provide somewhat mixed evidence for a visual prioritization of scorpions. Failing to support our primary hypothesis, these dangerous animals were not detected more rapidly than grasshoppers across trials. However, scorpions did garner greater attention when presented on the screen, as evidenced by the greater number of distractor fixations during grasshopper-target searches. These findings are consistent with a recent eye-tracking study showing a preference to gaze towards scorpions when compared to both spiders and grasshoppers (Rudafolva et al., 2022).

Overall, these results contrast with previous studies showing that snakes, spiders, and lions tend to be detected significantly faster than comparable non-threatening stimuli (e.g., Lobue, 2010; Gallup & Meyers, 2021; Gallup & Wozny, 2023). However, as was the case here, not all studies have provided robust support for the existence of threat detection mechanisms for these recurrent predators. For example, studies on both humans and non-human primates show a faster detection of snakes compared to spiders (Kawai, & Koda, 2016; Shibasaki & Kawai, 2011), and imaging studies in humans find a greater neurological activation to snake stimuli than spiders (e.g., He et al., 2014). In addition, recent studies have found that exposure to vigilance cues (i.e., yawning) has a greater effect on modifying attention towards snakes than it does for lions (Gallup & Meyers, 2021; Gallup & Wozny, in press). Consistent with Snake Detection Theory (Isbell, 2006), the available evidence best supports the presence of psychological adaptations for the rapid detection of snakes. We speculate that the special nature of snakes in capturing our attention could be due to differences in both the prevalence/encounter rate and lethality of these distinctive predators. Snake species are abundant across all continents and 24% of all snakes worldwide are venomous (Luiselli et al., 200). Furthermore, of the 3,700 snake species, 10% are dangerous to humans (Perry et al., 2020). By comparison, although nearly all spiders use venom, only 0.5% are harmful to humans (Hauke & Herzig, 2017). Similarly, only 30 species of scorpions are considered dangerous to humans (Chippaux, 2012). Consistent with these differences, envenomizations from snake bites kill ~100,000 more people each year than the total fatalities from spiders, lions, and scorpions combined (Cheng & Currie, 2004; Löe, J., & Röskaft, 2004; Nentwig & Kuhn-Nentwig, 2012; Perry et al., 2020). If the current predation risks reflect ancestral conditions, selection for visual detection mechanisms would have been much stronger for snakes, which could explain the current results and the mixed findings in the literature for other predators (i.e., spiders and lions).

There are limitations to the current study. First, this investigation only compared the detection and distraction properties of scorpions to one other stimulus, and thus future work could aim to include a variety of additional comparisons. One potentially fruitful area of study would be to examine how the detection of scorpions compares to spiders, as this could provide a further test of the spider-scorpion generalization hypothesis (Rudolfová et al., 2022). Second, nearly 90% of participants sampled here reported having no experience with scorpions in the wild, and thus it remains possible that studies in warmer climates, where scorpions are common, would yield different results. For example, African populations report a higher fear of scorpions and a greater preference to look at these animals compared to people from

Europe and the United States (Vetter et al., 2018; Rudafolva et al., 2022; Fyrnta et al., 2023), thus it is possible that experiential factors could also increase detection latency. Consistent with this notion, one study found that spider detection was enhanced among participants that already feared spiders (Mayer et al., 2006). Removing the participants in the current study that had encountered scorpions in the past did not impact the findings, though the sample size was too small for statistical comparisons. The current study was designed to test the innateness of a scorpion detection mechanism, but future research could aim to run similar experiments within populations that inhabit the same geographic regions as harmful scorpions. Third, the target-discrimination task used in the current study might not be ideal for investigating evolved mechanisms for threat detection. The current design was chosen based on the traditional use of this task within the literature assessing snake detection and fear modules (e.g., Öhman et al., 2001; LoBue & DeLoache, 2011; Yorzinski et al., 2014), though future research in this area could employ more ecologically valid target detection tasks, such as an inattentional blindness paradigm (New & German, 2015). Finally, although prior work suggests that modifying images to grayscale does not impact the detection of threatening stimuli (Flykt, 2005; Hayakawa S., Kawai N., and Masataka, 2011; Yorzinski et al., 2014), follow up work in this area could assess how the detection latencies differ when using color images since this was the first study to investigate scorpion detection.

In summary, this investigation adds to an emerging line of evolutionarily informed research on human responses to scorpions (Vetter et al., 2018; Azil, Yakub, Hassan, & Sharip, 2021; Frynta et al., 2021; 2023). The current findings do not support the hypothesis that humans possess psychological adaptations for the rapid detection of scorpions, though when presented as distractor stimuli they did elicit greater attention. Overall, these results provide mixed support for the visual prioritization of scorpions, though further research in this area is needed.

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