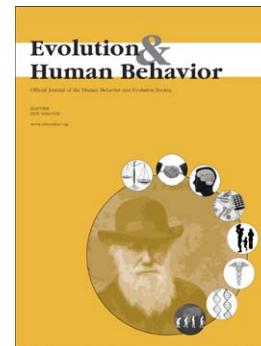


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## Spiders at the Cocktail Party: An Ancestral Threat that Surmounts Inattentional Blindness

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### Abstract

The human visual system may retain ancestral mechanisms uniquely dedicated to the rapid detection of immediate and specific threats (e.g. spiders and snakes) that persistently recurred throughout evolutionary time. We hypothesized that one such ancestral hazard, spiders, should be inherently prioritized for visual attention and awareness irrespective of their visual or personal salience. This hypothesis was tested using the inattentional blindness paradigm in which an unexpected and peripheral stimulus is presented coincidentally with a central task-relevant display. Despite their highly marginalized presentation, iconic spiders were nonetheless detected, localized, and identified by a very large proportion of observers. Observers were considerably less likely to perceive 1) different configurations of the same visual features which diverged from a spider prototype, or “template”, 2) a modern threatening stimulus (hypodermic needle) comparable in emotional salience, or 3) a different fear-irrelevant animal (housefly). Spiders may be one of a very few evolutionarily-persistent threats that are inherently specified for visual detection and uniquely “prepared” to capture attention and awareness irrespective of any foreknowledge, personal importance, or task-relevance.

Keywords: Attentional capture, fears, inattentional blindness, biological preparedness

## Spiders at the Cocktail Party: An Ancestral Threat that

### Surmounts Inattentional Blindness

#### 1. Introduction

In our daily, modern life, the ability to maintain focused attention to tasks despite numerous potential distractions is a highly desirable ability. However, critical events may require an interruption of our focused attention despite their irrelevance to any exigent goals and expectations (Most, Scholl, Clifford, & Simons, 2005). Such critical events can be physical and non-conceptual. For instance, looming objects provoke automatic responses for avoiding bodily injury such as reflexive orienting (Franconeri & Simons, 2003), defensive eye blinks (Yonas, 1981), and avoidant head jerks (Yonas et al., 1977). Another large class of important events is of a learned, conceptual, and personal nature. In the famous “cocktail party” effect, for example, our name said aloud in a neighboring conversation strongly commands our attention (Wood & Cowan, 1995). We propose that the visual system may be inherently prepared to orient attention to a third class of events – specific types of objects that have been of recurring and immediate importance over evolutionary time (Coss & Goldthwaite, 1995; New, Cosmides, & Tooby, 2007; Tooby & Cosmides, 1990).

Emotional disorder researchers have long-debated whether the high frequency of fears and phobias for ecological threats such as snakes and spiders reflect a “biological preparedness” for detecting and surviving the persistently recurring hazards of our ancestral environments (Marks & Nesse, 1994; Öhman & Mineka, 2001; Seligman, 1971). Some of the most directly studied examples of this kind are angry faces (e.g. Öhman, Lundqvist, & Esteves,

2001), snakes (e.g. Öhman & Mineka, 2003), and spiders (Öhman, Flykt, & Esteves, 2001b), each of which have been advanced as model instances of biologically prepared fears.

Human faces, though, are at least as important in modern society as they have been in ancestral environments, which complicates the attribution of their attentional capture to ontogenetic or phylogenetic causes. Spiders, on the other hand, rarely constitute a serious physical threat to people today. Only about 200 of the approximately 40,000 extant spider species pose serious medical concerns to healthy adults by envenomating bites (Diaz, 2004). Medically confirmed fatalities are extremely rare – around six annually in the U.S. (Langley, 2005) and less than 200 annually worldwide (Russell, 1991).

Yet, the spider genus, *Latrodectus* (the widow spiders), present a particularly illustrative case for the commonly held – but rarely examined – assumption that spiders were a persistent and potentially injurious feature of humans' ancestral environments. Species of *Latrodectus* are now found on every continent (except Antarctica), however, there is a particularly high density of species in southern Africa where they likely originated (Garb, González, & Gillespie, 2004). Although there is little or no fossil evidence of *Latrodectus*, amber fossil specimens of its closest sister genus, *Steatoda* (Arnedo, Coddington, Agnarsson, & Gillespie, 2004), have been dated to the mid-Eocene epoch (48.6 – 40.4 million years ago; Berland, 1939; Petrunkevitch, 1942). For comparison, an ancient predatory threat to primates, snakes, evolved envenomating bites by 60 million years ago (Vidal, 2002). Their continuous coexistence with the catarrhine species (Old World monkeys and apes) may have compelled profound evolutionary changes to those primate species' perceptual systems in order to detect snakes pre-attentively – rather than evolve a venom resistance like other mammals (Isbell, 2006; Le et al., 2013).

Unfortunately, comparative and paleobiological evidence is not likely to uncover when – or the first ancestral species in which – a behaviorally identifiable snake or spider “detector” might have first arose (but see Isbell, 2006 for review).

Although there are still far more snake bites and fatalities (Kasturiratne et al., 2008), the effects of widow spider bite envenomation, termed latrodetism, are considered to be the most medically important spider bite syndrome worldwide (Graudins et al., 2012). Widow spider venom contains a phylogenetically unique and extremely potent neurotoxin,  $\alpha$ -latrotoxin, whose effects are specific to vertebrates – even though widow spiders primarily prey on invertebrates (Garb & Hayashi, 2013).  $\alpha$ -latrotoxin originated in a common ancestor of the *Latrodectus* and *Staetoda* genus (e.g. false black widows) but evolved a far greater vertebrate-specific toxicity in *Latrodectus* soon after their divergence (Garb & Hayashi, 2013). In humans,  $\alpha$ -latrotoxin produces severe muscle pain, cramps, nausea and other complications that can be incapacitating for days and remain debilitating for weeks thereafter (Maretić, 1983). Since the advent of antivenom, mortality rates are less than 1%, but reports for pre-antivenom populations range from 4% to 8% for healthy adults (Bettini, 1964). Widow spider bites pose an even more significant physical threat to pregnant (Russell, Marcus, & Streng, 1979; M. D. Wolfe, Myers, Caravati, Rayburn, & Seifert, 2011), young, elderly, and infirm individuals (Müller, 1992).

In the consideration of just one spider genus, it appears that a number of *Latrodectus* species with potent, vertebrate-specific venoms populated Africa long before hominoids and cercopithecoids diverged (Steiper, Young, & Sukarna, 2004) and have coexisted there with hominoids for tens of millions of years since. This increasing paleobiological evidence corroborates the common presumption that humans were at perennial, unpredictable, and

significant risk of encountering highly venomous spiders in their ancestral environments. Even when not fatal, a widow spider bite in the ancestral world would often still leave one incapacitated for days or even weeks – terribly exposed to other dangers and/or a considerable burden to family and friends.

But avoiding spiders and such serious consequences is not difficult, providing they are noticed in time. Widow spiders, though, are typically darkly-colored (black or brown) with body lengths as small as 8 mm and typically hide in dark recesses. Detection, therefore, is the critical arbiter of success in such encounters – any improvements to the sensitivity, vigilance, reliability, and speed of faculties for their detection would have been of significant selective advantage. Proponents of the Snake Detector theory have similarly reasoned that predation from snakes primarily drove catarrhine species towards more sophisticated detection abilities rather than physical defenses such as a physiological resistance to venoms (Isbell, 2006; Le et al., 2013). The perceptual mechanisms for avoiding venomous bites appear to be more cost-effective than the physiological measures necessary to survive them asymptotically.

Since spiders were of far greater significance to survival in ancestral environments than they are in today's environment, they constitute a uniquely well-suited test category of inherent – that is, not acquired – attentional priorities (New et al., 2007). Any ability of these ancestral threats to capture attention and awareness may persevere today – despite their infrequency and inconsequentiality to modern life – as adapted behavioral vestiges of our visual cognitive systems: not as attentional priorities acquired haphazardly through experience (Coss & Goldthwaite, 1995).

Spiders and snakes have been examined with most of the paradigms used to measure attentional capture – though often with mixed results. In the most-used paradigm, visual search, spiders and snakes have been inferred to capture visual attention via their efficient detection in visual search tasks (LoBue & DeLoache, 2008; Öhman, Flykt, & Esteves, 2001a; Pflugshaupt et al., 2005). However, other visual search studies have suggested that such ready detection might be common to all animals – both threatening and nonthreatening (Jackson & Calvillo, 2013; Lipp, Derakshan, Waters, & Logies, 2004; Tipples, Young, Quinlan, Broks, & Ellis, 2002) or to all threatening objects – both ancestral and modern (Blanchette, 2006; Brosch & Sharma, 2005).

There are many factors involved in the visual search task that can complicate the inference of attentional capture. Visual searches are conducted with top-down guidance (J. M. Wolfe, Horowitz, Kenner, Hyle, & Vasan, 2004) and search templates (Schmidt & Zelinsky, 2009), that can differ in effectiveness between categories of real-world objects (Levin, Takarae, Miner, & Keil, 2001). Further, training can imbue entirely neutral targets with attention-recruiting properties (Kyllingsbæk, Schneider, & Bundesen, 2001; Shiffrin & Schneider, 1977), and the visual search task itself commonly broadens the distribution of attention which can generally increase detection efficiency (Belopolsky, Zwaan, Theeuwes, & Kramer, 2007). Therefore, the efficient detection of any such categories of objects (e.g. snakes, butterflies, and needles) in conventional visual search tasks may not clearly adjudicate between objects that automatically capture attention and awareness, and those whose detection is mediated by a combination of implicit and explicit factors (Cave & Batty, 2006; Most et al., 2005).

In a related paradigm, the irrelevant singleton task, the addition of spiders to an array interfered with viewers' searches for a target object – despite the spiders' irrelevance to the prescribed task. However, butterflies did so as well, and the apparent diversion of attention from the prescribed task to both animals was especially pronounced in individuals highly fearful of spiders (Devue, Belopolsky, & Theeuwes, 2011). The expectation that spiders would be displayed increased the spider-fearful participants' monitoring for – and interference by – both fear-relevant and neutral stimuli. Yet, even those especially fearful individuals were capable of ignoring the appearance of additional objects when spiders were very unlikely to appear. Such probability information – deducible from repeated presentations of salient stimuli – can guide attention and monitoring whenever (Devue et al., 2011) and wherever warranted (Notebaert, Crombez, Van Damme, De Houwer, & Theeuwes, 2010).

The evidence for ancestral threats being prepared – or inherently prioritized – for attention is thus generally mixed but also commonly complicated by top-down information and guidance. Undoubtedly, the ability to quickly find threats of all kinds when trying or alerted to do so is of great survival value. However, dangers such as spiders and snakes occur unpredictably and generally so infrequently that they need to be detected and brought to awareness largely absent any foreknowledge, intentions, or expectations. To minimize such top-down control, the current study presented spiders – a prototypical ancestral threat – using the inattentional blindness (IB) paradigm. Here, an unexpected stimulus is presented peripherally to—and coincidentally with—a central, task-related stimulus (Newby & Rock, 1998). The experimental stimulus is only tested in one trial for each participant, since even one presentation of a stimulus can facilitate the detection of subsequent occurrences via priming

(Tulving & Schacter, 1990) and/or expectations (Mack & Rock, 1998). The IB paradigm is thus a very rigorous measure of attentional capture relative to approaches that repeatedly display experimental stimuli. Importantly, the IB task more closely emulates the conditions under which humans have typically encountered spiders and snakes in their ancestral and modern environments, that is, largely without foreknowledge, warning, or task-relevance.

The IB paradigm can not only measure how likely unexpected objects are to be detected, but which of their qualities (e.g. location, shape) are registered during their single, brief exposure. The real-world function of attentional capture is to recognize significant objects and events and prompt some adaptive response. The ability to divert attention from current tasks is a necessary but not sufficient quality of threatening objects and events, whether ancestral or modern. As Most and colleagues reason, should a child appear in front of your car as you tune the radio, the important result is not that you are slower turning the radio knob, it is that you steer away from the child (2005). The threshold of success for perceiving threats is particularly high: that is to become aware of their presence, their location, and critically for reacting adaptively – their identity. Being distracted from a possibly crucial task while remaining unaware of the potential threat constitutes the worst of both worlds.

In light of their evolutionarily-persistent threat to survival, spiders are hypothesized to be exceptionally capable of capturing attention and propagation into conscious awareness even when completely unexpected and irrelevant to any exigent goals. We predicted that iconic, prototypical spiders (Figure 1.A and 1.C) will be very frequently detected, located, and identified when presented in an inattentional blindness task. This was tested in a first

experiment and close conceptual replication along with items of visual and categorical interest for comparison.

A number of stimuli were included in both experiments to control for the iconic spiders' lower-level visual characteristics and to closely delimit some visual features that may be integral to their efficient detection. Seminal research on IB suggested that the shapes of most simple objects presented under these display conditions go largely unregistered (Mack & Rock, 1998). However, the exact shape of some highly meaningful objects significance such as the participants' own names, can be closely specified through overlearning and are readily detected (Mack, Pappas, Silverman, & Gay, 2002; Mack & Rock, 1998). Whereas our own written name is specified through experience, for example, some objects of persisting biological importance and visual typicality – such as faces and spiders – may be inherently specified in a template-like fashion (Öhman & Mineka, 2001). These perceptual templates may be triggered pre-attentively by detecting some specific configuration of simple visual features (Öhman, 2008). In one study that largely precluded conditioning experiences, 5-month olds were found to attend stimuli falling within a perceptual template of spiders more than to different configurations of the same visual elements (Rakison & Derringer, 2008).

The defining visual configuration of spiders appears to be the radiation of multiple segments from a central mass point with "legginess" being the most frequently reported frightening feature by spider-fearful individuals (Aronoff, Barclay, & Stevenson, 1988; Davey, 1992). This suggests that a "spider template" should encompass the range of configurations in which spiders naturally appear, including "curled up", even when such a stimulus is explicitly categorized as an innocuous flower – a manipulation following Vuilleumier and Schwartz

(2001). We predicted that the display of a clover-like object in Experiment 1 (Figure 1.B) – formed through reorganization of the prototypical spider's features (Figure 1.A) – would satisfy the purported spider template and capture attention and awareness in the same fashion as the prototypical spider. In Experiment 2, the prototypical spider (Figure 1.C) was reorganized so that many segments were chained together rather than radiate directly from the central mass – differing critically from the spider template (Figure 1.D). This configuration was predicted to be unlikely to capture attention and awareness despite its preservation of all of the prototypical spider's lower- and mid-level visual attributes that are important for object recognition (e.g. vertices, line junctions and terminations; Biederman, 1987; Gibson, Lazareva, Gosselin, Schyns, & Wasserman, 2007; Szwed, Cohen, Qiao, & Dehaene, 2009).

The spider template may not require curvilinear features, even though curvilinearity is more characteristic of living things than nonliving things (Kurbat, 1997) and which can guide their detection in visual search tasks (Levin et al., 2001). To test whether curvilinearity is integral to the spider template, rectilinear versions of each prototypical spider were constructed for both experiments. These rectilinear variants were composed entirely of straight lines and rectangles comparable to the sizes and lengths of the original curvilinear features (Experiment 1: Figure 1.E; Experiment 2: Figure 1.G). These rectilinear spiders were predicted to fall within the spider template and consequently often capture attention and awareness.

To control for visual salience, three additional items were constructed by reconfiguration of both rectilinear spiders' radiating segments (Figure 1.F in Experiment 1; 1.H in Experiment 2) and by enclosure of the Experiment 1's rectilinear spider with additional

segments (Figure 1.I). Although resulting, in the latter case, in increased salience in terms of area and number of features these stimuli were all predicted to fall outside of the spider template and thus be more susceptible to inattentional blindness.

To evaluate another evolutionarily-motivated account of attentional biases, the animate-monitoring hypothesis (New et al., 2007; New et al., 2010), a second animal (housefly: Figure 1.N) was included in Experiment 2 along with its scrambled visual control (Figure 1.O). In this account, people and animals have been of such longstanding importance to survival that they have become an inherent priority for visual attention and monitoring categorically.

Participants shown two rapidly alternating scenes more quickly and frequently detected changes to animate objects – including people and animals of all kinds – than changes made to inanimate objects such as tools, plants, or buildings. Without any direction as to the category of the target objects – unlike that provided in visual search – participants' spontaneous selections for attention were strongly and immediately biased to animate objects. Some visual search studies have also found fear-irrelevant animals (e.g. horses) to be found more efficiently than inanimate objects (Jackson & Calvillo, 2013; Lipp et al., 2004; Tipples et al., 2002).

The animate-monitoring hypothesis espouses that animate objects are inherently prioritized for visual attention. However, only a few forms such as the human face and figure, snakes, and spiders have likely been of sufficient structural invariance, temporal persistence, and potential threat to bring about a corresponding perceptual template for their detection (Blumstein, Daniel, Griffin, & Evans, 2000; Coss & Goldthwaite, 1995; Öhman & Mineka, 2001). The appearance of other animals would – given the diversity and mutability of their forms – likely have to be learned through personal experience or social learning (Barrett & Broesch,

2012). It is predicted here that spiders – by virtue of a dedicated perceptual template – will be uniquely capable of capturing attention and awareness under conditions in which other animals (i.e. housefly) will often go undetected.

Finally, the rapid detection and awareness of spiders could conceivably be a result of more general pathways for learning about threatening objects such as conditioning and modeling (Rachman, 1977). If such attentional biases are largely developed through personal experience, hypodermic needles should often be feared and capable of capturing attention and awareness, since injected vaccinations are the rule, and spider bites the rare exception in modern society. When surveyed explicitly, hypodermic needles are generally comparable to spiders in terms of rated fearfulness (Bernstein & Allen, 1969; Fredrikson, Annas, Fischer, & Wik, 1996).

If such attentional biases are mediated through aversive experiences, individuals' reported fears of each type of threatening object (hypodermic needles or spiders) should predict how likely they are to detect, locate, and identify the object of their fear. Especially fearful individuals have demonstrated greater efficiency in visual searches for the objects they fear in some studies (Öhman, Flykt, et al., 2001b) but not others (Waters, Lipp, & Randhawa, 2011). An iconic hypodermic needle (Figure 1.L, 1.N) and corresponding scrambled visual control (Figure 1.D, 1.H) was included in Experiment 1 and 2 to test whether the capture of attention and awareness can be inculcated for modern threats via general learning pathways.

## 2.0. Method

## 2.1. Participants

In Experiment 1, 252 undergraduate students (mean age = 19; range 18-22; 50% male, 50% female) participated in the experiment for credit in an introductory psychology course. Being included later than the original six items, the enclosed rectilinear spider was presented to an additional 36 participants in the inattention trial.

In Experiment 2, 320 undergraduate students (mean age = 19.5, range 17 – 37; 86% female, 14% male) participated in the experiment for credit in an introductory psychology course.

## 2.2. Stimuli

Excepting the critical test stimuli, all images were generated largely following those described by Newby and Rock (1998). Each image was surrounded by a black annulus (26.6° in Experiment 1; 32.3° in Experiment 2) that extended to the edges of the viewable displays. All stimuli were either black or antialiased grayscale figures on a white background. Each trial began with a central fixation object (.3° black square in Experiment 1; 1.6° black square in Experiment 2) followed by two lines bisecting at the center of the display. The horizontal and vertical lines were .15° wide in Experiment 1 and .06° wide in Experiment 2. Both lines were separately chosen at random from four lengths: 6.6°, 8.1°, 9.6°, or 11.1° in Experiment 1 and 8.1°, 9.7°, 11.3°, or 12.9° in Experiment 2. This image was followed by a mask wherein the entire annulus was filled with Gaussian grayscale noise in Experiment 1 (Figure 1, top right) and Gaussian heterochromatic noise in Experiment 2.

In the fourth and seventh trial, the horizontal and vertical bars of the cross were the greatest length. A critical stimulus (Figure 1) was randomly chosen for each participant. The

critical stimuli were displayed at a number of angles and distances from fixation to ensure that these results are not position-specific (Efron & Yund, 1996; Newby & Rock, 1998). In Experiment 1, each critical stimulus was presented to three participants at each eccentricity of 2.2°, 6.4°, and 10.7° in each quadrant displaced along a 45° (Figure 1, bottom left). In Experiment 2, each critical stimulus was presented to five participants at each eccentricity of 4.1° and 8.0° in each quadrant displaced along a 45° (Figure 1, bottom left). Stimuli presented in each of the seventh, full attention trials were counterbalanced across the remaining stimuli and always differed from the stimulus presented in the previous, critical trial. Placements of stimuli in the seventh, full attention trial always differed from the fourth trial location and were counterbalanced across the four quadrants and three distances from the center in Experiment 1 and two distances in Experiment 2.

An independent group of participants ( $n = 20$ ) viewed the Experiment 1 stimuli under identical viewing conditions with instructions to find and identify the additional stimulus. The spider (17/20), hypodermic needle (16/20), and scrambled spider (categorized as a flower) (18/20) were all named according to their intended category by comparable proportions of individuals.

### 2.3. Procedure

Experiment 1 was displayed on 15" (13.86" VIS) CRT monitors at 75 Hz and controlled by PCs running Superlab 2.0 ("Superlab Pro for Windows," 1997). Experiment 2 was displayed on 22" (21.5" VIS) LCD monitors at 100 Hz and controlled by PCs running E-Prime 2.0 (Schneider, Eschmann, & Zuccolotto, 2002).

Participants were seated approximately 38 cm from the monitors in Experiment 1 and 50 cm in Experiment 2. They were informed that a fixation point would appear, followed by a cross with two bars. They were asked to respond with the keyboard (Experiment 1) or mouseclick (Experiment 2) whether the two bars were equal in length or, if differing, which bar was longer. The participants then performed four trials in which the fixation point (1000 ms), test cross (200 ms), and mask (500 ms) were presented to them and provided a response (Figure 2). After the fourth trial containing the additional experimental stimulus, the participant was asked, "Did you see anything in addition to the cross on that trial?" and which quadrant the additional stimulus appeared in. They were then asked to identify the stimulus in an array which in Experiment 1 included two variants chosen randomly from the spider stimuli and the two needle stimuli. Participants in Experiment 2 picked from all eight stimuli used in that experiment.

The next two trials were again simply line-judgments. The seventh trial, however, was preceded by instructions to not perform the line-judgment task and only observe the display. To evaluate whether the stimuli were comparable in their ease of detection, a different experimental stimulus was chosen at random for presentation in the seventh (full attention) trial, and the participants answered the same questions posed in the inattention trial.

The participants concluded the experiment by reporting the level of fear they felt to twelve items chosen from the Fear Survey Schedule III using a 1 (None) to 7 (Terror) scale (Wolpe & Lang, 1964), notably including their fear of hypodermic needles (3<sup>rd</sup> item) and spiders (7<sup>th</sup> item).

### 3.0. Results

Binary logistic regressions were computed for each of the dichotomous outcomes – target stimuli detection, location, and identification – with the target stimuli displayed in the critical “inattention” trial as the categorical predictor of performance. An additional dichotomous outcome, termed “full report”, was calculated as success in all three measures (detection, location, and identification) or failure in any measure and similarly regressed on the critical stimulus type. In Experiment 1, critical stimulus type was a significant predictor of target detection [ $\text{Wald}_6 = 16.38, p = .012$ ], localization [ $\text{Wald}_6 = 19.15, p = .004$ ], identification [ $\text{Wald}_6 = 70.45, p < .001$ ], and of full report [ $\text{Wald}_6 = 39.87, p < .001$ ]. In Experiment 2, critical stimulus type was not a significant predictor of target detection [ $\text{Wald}_7 = 9.58, p = .214$ ], nor of target localization [ $\text{Wald}_7 = 11.16, p = .132$ ]. However, critical stimulus type was a significant predictor of target identification [ $\text{Wald}_7 = 51.92, p < .001$ ] and of full report [ $\text{Wald}_7 = 42.65, p < .001$ ].

In each regression, simple contrasts were conducted between the reference category, spider (Figure 1.A and 1.E.), and each of the other stimuli included in their respective experiments. As Figure 3 illustrates, all of the stimuli in Experiment 1 falling within the spider template – spider, scrambled spider, and rectilinear spider – were all equally likely to be detected (all  $p$ 's  $> .5$ ). However all critical stimuli falling outside of the spider template – the scrambled and enclosed rectilinear spider and the intact and scrambled hypodermic needle – were significantly less likely to be detected than the spider stimuli (all  $p$ 's  $< .05$ ). In Experiment 2, the likelihood of detection was comparable for nearly all of the target stimuli, excepting only a smaller likelihood of detecting hypodermic needles.

In Experiment 1, the likelihood of accurately reporting the target location was greatest for – and comparable between – the spider and rectilinear spider. The scrambled, scrambled rectilinear and enclosed rectilinear spider and the intact and scrambled hypodermic needle were all significantly less likely to be accurately localized (all  $p$ 's < .05). Although target category was not a significant predictor of localization performance in Experiment 2, a similar pattern for performance can be seen in which the spider and rectilinear spider were most likely to be accurately localized.

In Experiment 1, the likelihood of accurately identifying the target was greatest and – and comparable between – all the stimuli falling within the spider template ( $p$ 's > .15). The scrambled rectilinear spider and intact and scrambled needle were far less likely to be detected ( $p$ 's < .0001), although the enclosed rectilinear spider was not ( $p$  = .32). In Experiment 2, the prototypical spider was exceptionally likely to be accurately identified – significantly more so than the rectilinear spider ( $p$  < .05), and very highly significantly more so than all of the other experimental stimuli ( $p$ 's < .0001).

The identification performance in Experiment 2's seventh trial was not comparable for all stimulus types. Identification performance was still high for the three theoretically-relevant stimuli – spiders, needles, and houseflies – so is not thought to significantly qualify their performance in the inattentional trials. One likely reason for the particularly lower identification rates in Experiment 2 lies in the presentation of all eight critical stimuli in the identification array, rather than four items in Experiment 1. Notably, half of the participants in Experiment 2 were asked to identify their critical stimulus from four very close distractors.

In Experiment 1, the likelihood of success in all three measures was again greatest and – and comparable between – all the stimuli falling within the spider template ( $p$ 's  $> .23$ ). The enclosed rectilinear spider was significantly less likely to be fully reported ( $p < .05$ ) and the scrambled rectilinear spider and intact and scrambled needles were far less likely to be fully reported ( $p < .001$ ). In Experiment 2, the prototypical spider was especially likely to be fully reported – significantly more so than the rectilinear spider ( $p < .05$ ), and far more likely than all of the other experimental stimuli (all  $p$ 's  $< .001$ ).

Finally, the participants shown the spider or hypodermic needle were combined from both experiments, and their three single dichotomous and compounded full report measures were each logistically regressed on their respective fear rating for that critical stimulus. Contrary to the learning hypothesis, the participants' reported fears of hypodermic needles did not predict whether needles shown in the critical trial would be detected [ $\text{Wald}_1 = .95$ ,  $p < .329$ ], accurately located [ $\text{Wald}_1 = .005$ ,  $p < .994$ ], identified [ $\text{Wald}_1 = .072$ ,  $p < .788$ ], or fully reported [ $\text{Wald}_1 = .010$ ,  $p < .992$ ]. Nor did the participants' reported fears of spiders predict whether spiders shown in the critical trial would be detected [ $\text{Wald}_1 = .996$ ,  $p = .318$ ], accurately located [ $\text{Wald}_1 = 2.096$ ,  $p = .148$ ], identified [ $\text{Wald}_1 = .0001$ ,  $p = .990$ ], or fully reported [ $\text{Wald}_1 = .469$ ,  $p = .493$ ]. Participant sex was not a significant predictor of performance by any outcome measure when included in the logistic regressions for spiders or hypodermic needles (all  $p$ 's  $> .5$ ).

#### 4.0. Discussion

First and foremost, this study demonstrated that spiders – a model instance of an evolutionarily-persistent threat – are uniquely capable of capturing observers' visual attention and awareness. Without any forewarning and despite their marginalized presentation, the prototypical spiders were detected, located, and identified by a majority of participants in both the original experiment and replication. Considerable evidence accrued with other approaches, notably the visual search and irrelevant singleton tasks, has revealed other inculcated (i.e. threat-relevant) and inherent (i.e. animate) attentional biases. However, when top-down guidance was minimized in the inattentional blindness task used here, only the ancestrally-relevant threat of an appearing spider proved capable of reliably capturing attention and awareness sufficient to guide an adaptive response. Surviving encounters with such physical threats in our ancestral environments depended on responding quickly the first time they appeared, not the hundredth or even second time.

Second, these results suggest that visual attention and awareness were allocated according to a very rapid and fine visual discrimination between those stimuli that lie within the purported spider template and those just outside of it. In Experiment 1, the spider was successfully reorganized to be explicitly identified as an innocuous flower, yet remain within the spider template. As predicted, that compliant configuration was comparable to the prototypical spider in most performance measures. Conversely, the prototypical spider in Experiment 2 was reorganized into a noncompliant configuration, and was far less likely to capture attention and awareness.

Curvilinearity was not predicted to be a requirement of the spider template, despite being an attribute that is strongly associated with animate objects and aids their detection in

search tasks (Kurbat, 1997; Levin et al., 2001). As predicted, the rectilinear spider was as capable of capturing attention and awareness as the prototypical, curvilinear spider In Experiment 1 and only slightly less so in Experiment 2. Again, simply reorganizing or enclosing the rectilinear features to conflict with the spider template substantially reduced their ability to capture attention and awareness.

Third, animate objects of all kinds may be inherently prioritized for visual attention (New et al., 2007). Animals are, irrespective of threat, efficiently detected in search tasks (Tipples et al., 2002) and strongly biased for attention in natural scenes (New et al., 2007; New et al., 2010). However, when presented here in one of the most rigorous tests of reflexive attention, spiders could be successfully reported on by a majority participants in every way (full report) whereas houseflies fell critically short of that criterion. Conversely, the reflexive capture of attention and awareness by spiders does not even require their categorization as animals. Performance was often comparable between identifiable spiders and stimuli which technically conformed to the spider template but that were otherwise categorically ambiguous (rectilinear spiders) or even explicitly identifiable as an inanimate object (i.e. the ‘flower’ in Experiment 1). Dedicated perceptual templates may make a very few forms, such as the human face and body, snakes, and spiders uniquely capable of capturing attention – even amongst the larger domain of animate objects inherently prioritized for attention.

Finally, these results failed in two ways to support the alternative hypothesis that all kinds of threatening objects (both modern and ancestral) can become able via general learning processes of reflexively capturing visual attention and awareness. First, hypodermic needles – commonly experienced and feared items in the modern environment – were considerably less

likely than spiders to be registered when displayed under conditions that minimized top-down guidance. This contrasts markedly with previous findings that threatening objects in general (both modern and ancestral) capture visual attention, but were obtained with paradigms complicated by top-down knowledge. It should be noted that the fear of hypodermic needles is included in blood-injection-injury phobia (Hamilton, 1995) and may also have a phylogenetic origin engendered by the ancestral persistence of puncturing wounds. However, blood-injection-injury phobia principally elicits disgust (Tolin, Lohr, Sawchuk, & Lee, 1997) and is associated with less immediate processing biases such as implicit memory rather than attention (Sawchuk, Lohr, Lee, & Tolin, 1999). Therefore, needle fears may reflect a domain-specific adaptation for surviving wounds and blood loss but one that is not inherently endowed with a perceptual template nor function primarily through attentional selectivity.

Second, if attentional priorities reflect differential learning and experience to kinds of threats (both modern and ancestral), individuals reporting more fear of a particular threat should have been more likely to register the objects they feared. However, the likelihood that an individual detected, located, or identified either fear-relevant stimulus was not related to the degree of fear that individuals reported for those respective objects. In previous research, individuals searched more efficiently for the objects (e.g. spiders and snakes) that they were especially fearful of (e.g. Öhman, Flykt, et al., 2001b). However, experimental paradigms which repeatedly present target objects not only for allow top-down guidance but also feedback from affective processes to increase attention, vigilance, and even perceptual sensitivity for subsequent fear-relevant events (see Davis & Whalen, 2001; Phelps & LeDoux, 2005 for reviews). Performance in these iterated tasks may thus correspond to individuals' fears and

anxieties of presented threats – the severity of which can be sizably mediated by direct and indirect conditioning experiences, developmental stage, and possibly pathology (e.g. Boyer & Bergstrom, 2011; Poulton & Menzies, 2002).

The brief display of test stimuli in the studies here, without forewarning or repetition, greatly reduced the extent that reentrant feedback from affective mechanisms could influence attention and perception (Vuilleumier, 2005). Nonetheless, stimuli falling within the spider template were registered by a majority of participants, irrespective of their fear of spiders – appearing to reflect a greater and less variable sensitivity to their appearance. The comparatively uniform sensitivity to spiders may instead result from the inherent prioritization of their critical features in perceptual and attentional processes which engage prior to – and irrespective of – cognitive and affective influences. The precocious emergence of these abilities for visually identifying (Rakison & Derringer, 2008) and selectively attending (LoBue, 2010) to spiders subserve – and perhaps even potentiate – the later development of fears, phobias, and anxiety about spiders (LoBue, 2012; Marks & Nesse, 1994; Mineka & Öhman, 2002).

Past studies have demonstrated how all manners of threatening objects are sooner attended and more efficiently detected than nonthreatening objects. In this study, though, spiders demonstrated a singular ability to surmount inattentional blindness and capture viewers' attention despite their very brief, unexpected, and peripheral appearance. The pressure to survive recurrent encounters with immediate threats like spiders and snakes in our ancestral environments has brought about what is perhaps best termed 'reflexive awareness' of their presence. Even the first, unexpected appearance of spiders are registered in awareness with sufficient speed to trigger – and information to guide – an immediate behavioral response.

Although reflexive awareness of any threat would be a tremendous advantage, only the basic forms of a few ancestral threats have likely persisted long enough for the adaptation of a corresponding perceptual template. Along with a few others like snakes and angry faces, spiders may thus constitute an evolutionarily-relevant threat that humans are not only biologically prepared to fear but also reflexively perceive.

## 4.0. References

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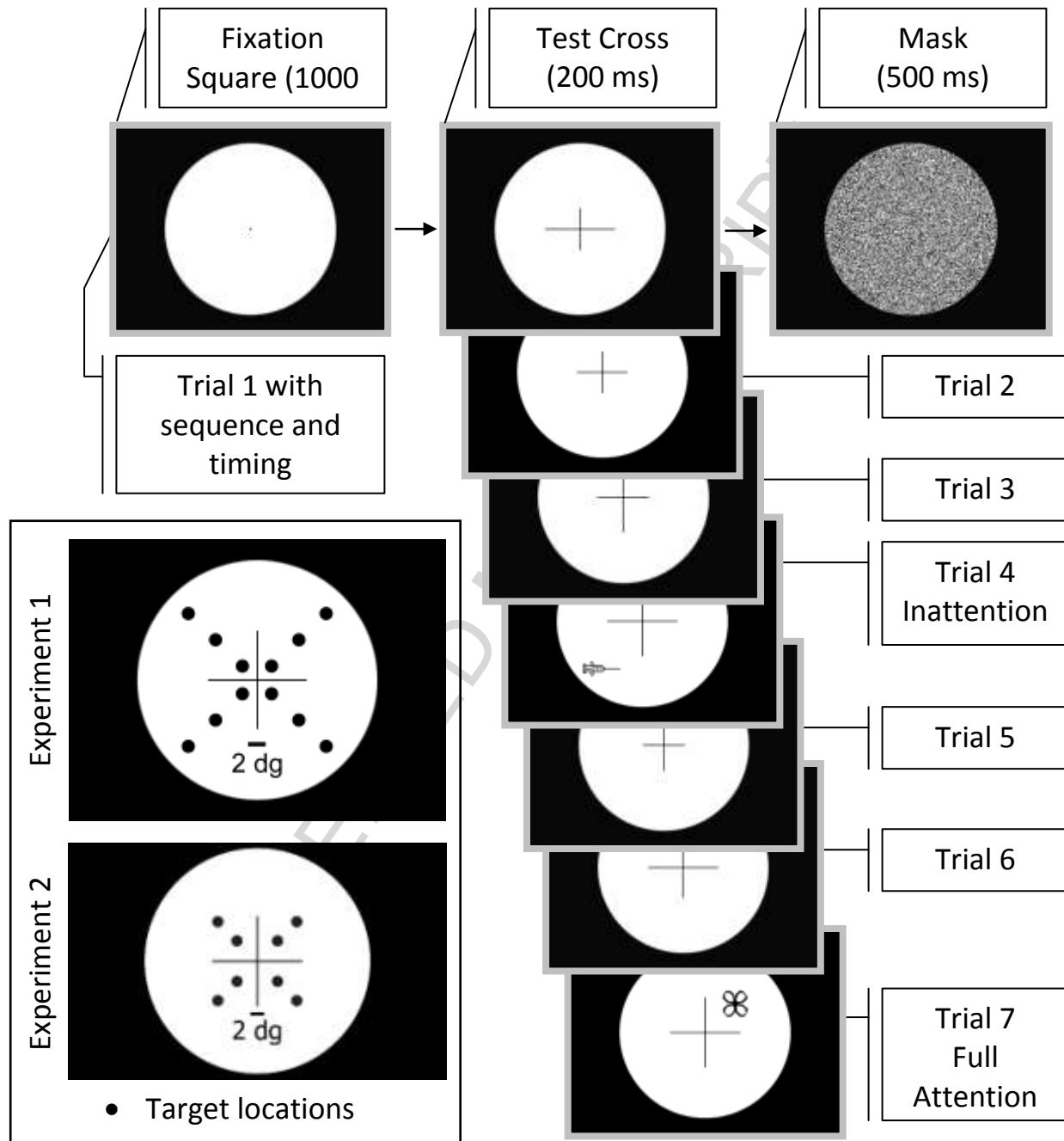
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Experiment 1		Experiment 2	
1.A Spider		1.B Scrambled Spider	
1.E Rectilinear Spider		1.F Scrambled Rectilinear Spider	
1.I Enclosed Rectilinear Spider			
1.L Scrambled Needle		1.M Hypodermic Needle	
		1.N Hypodermic Needle	
		1.O Scrambled Needle	

*Figure 1.* Stimuli presented in the fourth inattentional and seventh full attention trials.



*Figure 2.* The top row of images illustrates the sequence and timing used in each trial. The middle column moving down and to the right is an example illustrates the task-relevant and experimental stimuli presented in each of the seven trials. The bottom left image shows each of the possible locations where an experimental stimulus could appear.

Experiment 1	Inattention Trial				Detect & Locate & Identify	Full Attention Trial			
	Detect	Locate	Identify	Detect		Detect	Locate	Identify	Detect & Locate & Identify
Spider	81% ●	75% ●	72% ●	53% ●		100%	100%	97%	97%
Scrambled Spider (Flower)	75%	50% *	72%	39%		100%	94%	92%	86%
Rectilinear Spider	78%	75%	86%	61%		97%	94%	89%	86%
Scrambled Rectilinear Spider	56% *	39% **	17%	* ** 6%		97%	86%	78%	72%
Enclosed Rectilinear Spider	53% *	47% *	61%	* 28%		100%	94%	78%	64%
Hypodermic Needle	53% *	44% *	17%	* ** 14%		100%	97%	75%	75%
Scrambled Needle	50% *	42% *	11%	* ** 8%		100%	97%	72%	69%

Experiment 2	Inattention Trial				Detect & Locate & Identify	Full Attention Trial			
	Detect	Locate	Identify	Detect		Detect	Locate	Identify	Detect & Locate & Identify
Spider	80% ●	68% ●	63% ●	53% ●		100%	98%	93%	90%
Scrambled Spider	78%	43% *	** 18%	** 8%		100%	100%	100%	23%
Rectilinear Spider	75%	65%	* 40%	* 25%		100%	100%	100%	15%
Scrambled Rectilinear Spider	70%	55%	** 10%	** 5%		98%	95%	5%	5%
Hypodermic Needle	53% *	43% *	** 8%	** 8%		100%	93%	93%	88%
Scrambled Needle	75%	43% *	** 15%	** 13%		98%	95%	40%	40%
Housefly	73%	58%	** 10%	** 10%		98%	95%	55%	53%
Scrambled Housefly	68%	53%	** 8%	** 5%		100%	98%	23%	23%

\*p < .05, \*p < .01, \*\*p < .001, \*\*\*p < .0001

*Figure 3.* The percentages of participants in Experiments 1 and 2 who successfully detected, located, identified and fully reported the experimental stimuli displayed in the fourth inattentional trial (left) and seventh full attention trial (right). The category, spider, served as the reference category for each simple contrast and is denoted with a filled black circle to aid visual comparison.