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Noticing spiders on the left: evidence on attentional bias and spider fear in the inattentional blindness paradigm

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Abstract

Attentional biases in anxiety disorders have been assessed primarily using three types of experiment: the emotional Stroop task, the probe-detection task, and variations of the visual search task. It is proposed that the inattentional blindness procedure has the ability to overcome limitations of these paradigms in regard to identifying the components of attentional bias. Three experiments examined attentional responding to spider images in individuals with low and moderate to high spider fear. The results demonstrate that spider fear causes a bias in the engage component of visual attention and this is specific to stimuli presented in the left visual field (i.e., to the right hemisphere). The implications of the results are discussed and recommendations for future research are made.

Noticing spiders on the left: evidence on attentional bias and spider fear in the inattentional blindness paradigm

Evolutionary perspectives of fear suggest that it is an adaptive process enabling the detection of (and subsequent escape from) threat, particularly biologically relevant threatening stimuli such as spiders, snakes and angry faces (e.g., LeDoux, 1996; Öhman, 2006) which elicit enhanced attention even in human infants (Boyer & Bergstrom, *in press*) and in other species.

The detection of potential threat has obvious evolutionary utility and has been displayed in a range of species. In birds, chicks with lateralised brains, with a left eye (right hemisphere) dominance, are faster to detect threat appearing on the left during a food discrimination task (Rogers, Zucca & Vallortigara, 2004), display greater sensitivity to human faces (Rosa Salva, Regolin & Vallortigara, 2012) and gaze (Rosa Salva, Regolin & Vallortigara, 2007), respond to images appearing from the left with greater approach and attack responses (Rogers, 2000) and exhibit more distress calls (Rogers, 1997). Similarly, magpies showed a left eye (right hemisphere) bias to escape from potential threat and a right eye (left hemisphere) bias to approach threat (Koboroff, Kaplan & Rogers, 2008).

Fish demonstrate an initial bias to turn left when a predator appears, but after repeated testing turned right, which may reflect an inborn tendency to look at fearful stimuli with the left eye due to right hemisphere dominance (Cantalupo, Bisazza &

Vallortigara, 1995). Rats using the left eye only (and the right hemisphere) are shown to be as effective at detecting escape routes as animals using both eyes (Rogers, 1997).

Dogs have demonstrated similar lateralisation effects when presented with stimuli of varying emotional valence (Siniscalchi, Sasso, Pepe, Vallortigara & Quaranta, 2010). Results showed that dogs turned left more frequently to silhouettes representing snakes and cats, but no differences were found when the dogs were presented with images of other dogs. Tail wagging has also been demonstrated to be affected by the emotional valence of stimuli. Quaranta, Siniscalchi and Vallortigara (2011) found that dogs wagged their tails with greater amplitude to the right (demonstrating a left hemisphere bias) in response to owners, but with lower amplitude to the right when presented with cats, and to the left (right hemisphere bias) in response to a unfamiliar dominant dog, which suggests avoidance behaviour. Similarly, Siniscalchi, Sasso, Pepe, Dimatteo, Vallortigara and Quaranta (2011) found that dogs sniffed with the right nostril when they were presented with potentially aversive stimuli, such as vetenary sweat or adrenaline, which again suggests escape and avoidance behaviour mediated by the right hemisphere.

In human participants responses to threat can be especially exaggerated. Cognitive models of anxiety disorders suggest that people with elevated anxiety will, via preattentive processes, rapidly allocate their visual attention to threatening objects (e.g., Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg & IJzendoorn, 2007; Cisler & Koster, 2010; Eysenck, 1997; Mogg & Bradley, 1998; Peira, Golkar, Larsson, & Wiens, 2010; Williams, et al., 1988; 1997). Evidence informing these theoretical accounts comes primarily from three paradigms: the emotional Stroop task, the probe-detection task and variations of the visual search task.

Before considering the experimental evidence for attentional biases in more detail, a brief summary of “attention” is required. Attention clearly involves multiple distributed brain networks (Posner, Rueda, & Kanske, 2007) reflecting both endogenous (top-down) and exogenous (bottom-up) processes (Hopfinger & West, 2006), but one classic view (Posner & Petersen, 1990) is that the attentional system is comprised of three main facets or mechanisms. The initial orienting of attention to an object is controlled by the engage component. The removal of attention from an object is controlled by the disengage component. The shift component controls the movement of attention between different objects or areas in visual space. These individual components have not been fully accounted for in the literature on attentional biases in anxiety.

In reference to the methods used to inform cognitive models of attentional biases in anxiety disorders, the emotional Stroop task has largely been abandoned because its relevance to the attentional system has been questioned. For example, Williams et al. (1997) suggest that the colour naming latency displayed by anxious individuals when threatening words or pictures are presented may reflect processes beyond the attentional system, such as self-referential activity. Due to the interpretation difficulties with the Stroop task, the probe-detection task was developed (MacLeod, Matthews & Tata, 1986). During a probe detection task, participants are presented with two images simultaneously in either a horizontal or vertical configuration. After a delay, the images offset the screen and a probe replaces one of them. Participants are instructed to locate the probe as quickly as possible. Response times are taken as an index of where visual attention was allocated when the probe appeared.

Findings from the probe-detection task show that anxious individuals are faster to detect the probe when it replaces a threatening image in comparison with neutral images (within-participants design) or in comparison to low anxious control participants (between-participants design). Biases towards threatening images have been demonstrated in social phobia (Mogg, Philipott & Bradley 2004; Pishyar, Harris & Menzies, 2004a; Pishyar, Harris & Menzies, 2004b), spider phobia (Mogg & Bradley, 2006) and elevated trait anxiety (Mogg & Bradley, 1999; Wilson & MacLeod, 2003). There is also evidence to suggest that such biases are mediated by the right hemisphere (Fox, 2002; Mogg & Bradley, 2002) but the time taken to detect the probe does not provide an index of where visual attention is initially allocated (Fox, Russo, Bowles & Dutton , 2001). As such, it is unclear whether the initial "engage" component of visual attention is biased towards threat in anxiety states.

Attempts have been made to circumvent this problem. One method has been to reduce the stimulus onset asynchrony (SOA) from the traditional 500ms (MacLeod et al., 1986) to briefer durations. For example, Mogg and Bradley (2006) found an attentional bias towards spiders in spider fearful individuals at 200ms. Nevertheless, endogenous shifts in attention between stimuli can still operate within this time period, so it is not certain which stimulus is initially prioritised by the attentional system. The use of eye tracking methods to assess initial orienting share a similar problem. Retinal fixation is an imprecise measure of where visual attention is allocated because attention can move independently from eye movements (Mack & Rock, 1998). Thus, experiments are required that more precisely measure the engage component of visual attention.

Visual search tasks (Rinck, Reinecke, Ellwart, Heuer, & Becker, 2005) go some way to overcoming problems with the probe-detection task. In visual search tasks, participants are presented with a matrix of images; one image is the feared object (e.g., a spider) and the other images are innocuous (e.g., flowers). The time taken to detect the threatening image reflects the processing strategy participants are employing. Faster detection times regardless of the number of distractor or non-target items reflect rapid parallel processing, which is more likely to reflect biases in the engage component of visual attention. Slower detection times with increasing number of distractors are said to reflect serial search.

Different variations of the visual search task have been used to explore attention to phobic stimuli. These variations relate to the prior exposure of the stimulus to the participant. For example, Rinck, et al. (2005) suggest that studies can be divided into those that present the participant with the object beforehand (e.g., showing participants an image of a spider and then asking them to locate it during the experiment). This is termed the target search task. The second method involves the participant being asked to find the incongruent stimulus, without being informed what the image will be. This is termed the odd-one-out task. Results from both methods have demonstrated target detection biases in social phobia (Rinck & Becker, 2005) elevated trait anxiety (Byrne & Eysenck, 1995) and spider fear (Miltner, Krieschel, Hecht, Trippe & Weiss, 2004). Nonetheless, the prior presentation of stimuli, whether by showing the image before hand, or by verbal instruction that one might appear, is problematic. This is because, in real life situations, it is unlikely that even people will be constantly (and consciously) vigilant for, for example, spiders on a moment-to-moment basis. Thus, a more ecologically valid measure of visual attention towards feared objects is required.

To summarise, further work is needed to more precisely examine the role of the engage component of visual attention in regard to feared stimuli and increases in the ecological validity of methods are required. Additionally, further inspection of lateralisation effects in response to threat in humans is required. A method that has the potential to achieve these requirements is the inattentional blindness paradigm. Inattentional blindness experiments have been used to demonstrate that objects appearing within a person's visual field can go undetected when a person is engaged on a concurrent but unrelated visual task (Mack & Rock, 1998). In this task, participants are presented with a series of cross images at fixation and must judge whether the horizontal or vertical line is longest within 200ms. On the final trial, an unexpected object is presented in one of the quadrants defined by the cross. After the experiment, participants are asked if they noticed the additional object. Rates of inattentional blindness vary depending on the nature of the unexpected stimulus. Schematic smiling faces drew the attention of the majority of participants in Mack and Rock's (1998) experiments. However, when the direction of the mouth was reversed to show a sad expression, the majority of participants missed the stimulus.

Crucially, due to the object being unexpected and presented simultaneously with the distraction task, noticing the object is directly related to the engage component of visual attention. Furthermore, due to the novel and unexpected nature of the stimulus and the cross judgement task being presented centrally, there is a greater level of control over where the stimulus is placed, which allows for a more systematic investigation of the roles of the left and right hemispheres of the brain.

To our knowledge, only one study has been published that uses the inattentional blindness task to study attentional bias in anxiety disorders (Lee & Telch, 2008). The findings showed that social phobia was correlated with noticing negative facial expressions. However, prior to the experiment, participants were screened for social anxiety, which may have primed them and artificially elevated noticing rates. Secondly, the cross judgement task was presented in the parafovea and the critical stimulus appeared at fixation. This means that attention had to move from the fixation point to the cross. For the object to be noticed, attention would have to return to the area originally attended. Thus, Lee and Telch's (2008) results may better be conceptualised as fear relevant stimuli breaking through the Inhibition of Return phenomena, and thus may reflect a bias in the shift component of visual attention. The present series of experiments were designed to examine the role of the engage component of attention, while eliminating the role of expectation that a feared object will be presented, and varying the location of the stimulus to further investigate the roles of the left and right hemispheres of the brain.

The particular category of feared stimuli to be employed is that of spiders since they may have a special threat significance (Gerdes, Uhl, & Alpers, 2009) inducing high levels of disgust in spider phobics (Olatunji, Cisler, Meunier, Connolly, & Lohr, 2008). Even young infants have been shown to display attentional bias to spiders (Boyer & Bergstrom, *in press*; Rakison & Derringer, 2008) consistent with an innate disposition to respond to such stimuli, although aversive learning may account for the development of spider phobia (Purkis & Lipp, 2009). In any case, spider images would seem to offer a robust tool for exploring attentional bias to fear-inducing stimuli.

Experiment 1

Introduction

The aim of the first experiment was to examine the utility of the inattentional blindness experiment to examine attentional biases in spider fear. The hypothesis that spider fearful individuals notice a spider image when it is presented against expectation was examined.

Method

Participants

Participants were 25 males and 25 females recruited from members of the public visiting ‘At-Bristol’ Science Museum, UK, (mean age 37, SD = 10.2). All participants had normal or corrected to normal vision; none of the participants reported a history of neurological trauma or disease. The data from one participant was excluded due to an indecipherable response. Therefore, the total participants for this experiment were 49. After the experiment, none of the participants reported knowledge of the static inattentional blindness experiment. The study received ethical approval from a local ethics committee.

Materials

All of the images were displayed in the centre of a white circle (10.6cm) on a black background using E-Prime V1.2 (Psychology Software Tools, Inc). The first image was an asterisk in the centre of the circle (0.6°), serving as the fixation point (displayed for 1500ms). The second image consisted of two bisecting lines of different length (displayed for 200ms). The long line measured 4cm and subtended a visual angle of 4.6°. The small line measured 3.5cm and subtended a visual angle of 4°. The third image was a visual mask consisting of black and white shapes (displayed for 500ms), which covered the area of the screen previously defined by the circle. This sequence of image was presented four times. The unexpected critical stimulus (the spider) appeared along with the cross judgement task on the fourth trial. The spider represented a visual angle of 0.7° and was placed at a distance of 2.5cm (2.9° eccentricity) in the bottom right quadrant of the cross.

The experiment was separated into three stages. Participants were first presented with the inattention stage. This was when the dependent variable (i.e., noticing of the critical stimulus) was recorded. The experimenter asked questions to ascertain whether the critical stimulus had been perceived. The questions were:

1. ‘Did you notice anything additional on the screen that time?’

2. If yes: ‘Where was it located?’; If no: ‘Did you see anything in the bottom right side of the screen?’

3. If yes: ‘Can you tell me what it was?’ If no: ‘Proceed to next trial’.

In order to ensure that the stimulus was perceptible under different attentional conditions, two further stages were conducted. The second stage was the divided attention trial. Participants were asked to judge which line was longest while being instructed to look for anything additional to the cross. The third stage was the full attention trial. Here, the participants were instructed to ignore the line judgement task and look for anything additional that might appear on the screen. Data from these trials were recorded but later discarded. If any of the participants had failed to notice the spider on the full attention stage, their data from the inattention stage would have been discarded[1].

A forced choice test was used after the computer task to further examine object recognition and implicit perception (see figure 1). A card contained five distinct images of equal size that were randomly positioned on the card. Three images were geometric objects (circle, triangle, square). The remaining two images were the spider appearing in the experiment and a reconfigured image of the spider. Depending upon responses, participants were asked to select the image they noticed (participants classified as identifiers), or the stimulus that might have appeared (participants classified as ‘detectors’) or at random (participants classified as ‘inattentionally blind’).

After the computer task, participants also completed the Fear of Spiders Questionnaire (FSQ: Szysmanski & O’Donohue, 1995) and the depression subscale of the Hospital Anxiety and Depression (HAD) scale (Zigmond & Snaith, 1983). Both scales are included at the end of the manuscript.

< insert figure 1 about here>

Design

Participants were separated into two non-overlapping groups depending on scores from the FSQ. Participants scoring equal to or greater than 30 were allocated to the moderate to high fear group, and participants scoring equal to or less than 29 were categorised as having low fear. This separation was based on the mean score across the sample for the first experiment. There are inconsistencies in the literature with cut off points for the FSQ, with different authors using different separation points (Huiding & de Jong, 2006; Cochrane, Barnes-Holmes & Barnes-Holmes, 2008). However, across all of the experiments described here, the cut-off-points between low and moderate to high fear remained the same.

Participants were also separated into different, non-overlapping noticing categories (inattentionally blind, detector, identifier) on the inattention stage of the experiments.

Participants were categorised as inattentionally blind if they said they did not see anything, or if they reported an event that did not occur (for example, that the cross had moved). They were categorised as detectors if they verbally identified an object in the correct quadrant of the cross but were unable to say what it was. Finally, they were categorised as identifiers if they correctly identified the location and verbally identified the spider ("bug" and "insect" were also accepted). The forced choice test was used to further categorise participants. Because spider fearful individuals may be reluctant to output the word "spider" (Williams et al., 1998), participants who were able to detect the correct location and correctly identified the object on the forced choice test were classified as identifiers. This resulted in a 2 (fear group: *low* vs. *moderate-high*) x 3 (noticing category: *inattentionally blind* vs. *detector* vs. *identifier*) design. All analyses were conducted using multidimensional chi-square tests. Fisher's exact test is reported where expected frequencies were less than 5. Statistical power is reported using the *phi* statistic (ϕ), which is used to measure the level of association between two variables (Rosenthal & Rosnow, 1991). In line with conventions in psychology, correlation coefficients of 0.4 and below were regarded as low, 0.5 to 0.7 as medium and effects larger than 0.8 as high.

Procedure

Visitors attending the science museum were approached and invited to participate in an experiment 'designed to examine the link between perception and emotion'. No information regarding the presentation of the spider was given. The participants were provided with a set of standardised instructions and, upon confirmation of understanding, asked to place their chin on a chin rest (50cm from the screen) and began a single practice trial.

The experimenter initiated each of the trials across the inattention, divided attention and full attention stages. After the task had offset the screen, participants were asked to report which line was longest. These data were recorded to ensure the instructions were understood, but were later discarded. After the fourth trial when the spider was presented, participants were asked if they noticed anything additional to the cross on the screen and their responses were categorised and recorded. After the computerised task, the participants were asked to complete the forced-choice and psychometric measures.

Results

When the participants were separated into low (n = 37) and moderate to high (n = 12) fear groups, Mann-Whitney tests revealed that the groups differed significantly on the FSQ ($U = .000$, $N_1 = 37$, $N_2 =12$, $p = .00$) but not on depression ($U = 181.500$, $N_1 = 37$, $N_2 = 12$, $p = .34$). A multidimensional chi square test with an exact option found no significant association between the fear groups and noticing categories ($\chi^2 = .166$, $df = 2$, $p = 1.0$ $\phi = .02$) on the inattention trial. The divided and full attention stages were not inferentially analysed. Table 1 presents the noticing rates for the low and moderate to high fear of spiders groups on the inattention trial.

< Insert table 1 about here >

Discussion

The analysis of association between fear status and noticing categories did not reveal a significant effect. Specifically, the hypothesis that elevated fear would be associated with increased identification rates, was not supported. However, this may have been caused by the size of the stimulus, which was relatively small. Therefore, in experiment 2, the size of the stimulus was increased.

Experiment 2

Introduction

The previous experiment yielded no significant association between fear status and noticing rates on the inattentional blindness experiment. However, anecdotal reports from spider fearful individuals suggest that the degree of fear they experience depends upon the size of the spider. Therefore, the purpose of the second experiment was to examine whether a larger spider would increase identification rates in spider fearful individuals.

Method

Participants

Participants were 21 males and 28 females (mean age 37, SD =13.6) and were recruited from the Cheltenham Science Festival. All participants had normal or corrected to normal vision; no participants reported a history of neurological trauma or disease and no participants reported having epilepsy. After the experiment, none of the participants reported knowing the static inattentional blindness paradigm.

Materials

In this experiment, the critical spider stimulus measured 0.9cm and subtended a visual angle of 1°. This was chosen because it is below the 1.1° retinal size threshold reported by Mack and Rock (1998). Again, the spider appeared in the bottom right quadrant of the cross, 2.5cm (2.9° eccentricity) from fixation. The forced choice test was modified in line with the spider size increase. All other materials remained the same as experiment 1.

Procedure and Design

Members of the public attending the science festival were approached and asked if they would be willing to participate in a study 'examining the link between perception and emotion'. No further details about the hypothesis were given. The same cut-off points used for the FSQ in experiment one were used in experiment two. All other elements of the procedure and design remained the same as the previous experiment.

Results

When the participants were separated into moderate to high (n = 13) and low (n = 36) fear groups using the FSQ, the groups differed significantly on the FSQ (U = .000,

N_1 = 36, N_2 =13, p = .00) but not on depression (U = 227.000 N_1 = 36, N_2 =13, p = .87).

A multidimensional chi-square test with exact significance option revealed no significant association between fear status and noticing categories (χ^2 = 1.761, df = 2, p = .48, ϕ = .19) on the inattention trial. The divided and full attention stages were not subjected to inferential analyses. Table 2 presents the noticing rates for both the low and moderate to high fear of spiders groups on the inattention trial.

< Insert table 2 about here >

Discussion

Analysis of the relationship between fear status and noticing categories or rates revealed no significant association. In particular, the predicted association between elevated fear status and spider detection was not observed. The results suggest that despite an increase in size, individuals with heightened fear of spiders do not display an engagement bias towards spiders. However, there is evidence to suggest that the left visual field (right hemisphere) may be more specialised for detecting threat in a range of different species (Cantalupo et al., 1995; Koboroff et al., 2008; Quaranta et al., 2011; Rogers, 1997, 2000; Rogers et al., 2004; Roso Salva et al., 2012; Siniscalchi et al., 2010) and this may be particularly so for people with elevated anxiety. For example, Fox (2002) and Mogg and Bradley (2002) suggest that the right cerebral hemisphere might be more sensitive to threat detection. In the final experiment, the spider image was therefore moved to the left visual field (left quadrant of the cross) and so initially processed in the left cerebral hemisphere.

Experiment 3

Introduction

The previous two experiments suggest that spider fearful individuals do not exhibit biases in the engage component of visual attention when spiders are presented against expectation. Nevertheless, there is evidence to suggest that the left and right cerebral hemispheres have different roles in threat detection, with the right cerebral hemisphere (and left visual field) displaying greater sensitivity, both in other species (e.g., Rogers, 1997) and in anxiety states (Fox, 2002; Mogg & Bradley, 2002). The previous experiments placed the spider image in the right visual field and thus projected the image to the left cerebral hemisphere. The current experiment places the same spider image as experiment two in the left visual field (left quadrant of the cross) to examine the role of the right hemisphere.

Method

Participants

The participants for the experiment were 21 males and 25 females (mean age 37, SD = 15.2), recruited from members of the public visiting the Glasgow Science Centre. All participants had normal or corrected to normal vision. No participants reported a history of neurological trauma or disease, and no participants reported having epilepsy. After the experiment, none of the participants reported knowing the static inattentional blindness paradigm.

Materials

In this experiment, the spider appeared in the bottom left quadrant of the cross, 2.5cm (2.9° eccentricity) from fixation. Other than this modification, the spider stimulus remained the same as in experiment two, measuring 0.9cm and subtending a visual angle of 1°. The forced choice was the same as was used in experiment two. All other materials remained the same as the previous experiments.

Procedure and Design

Members of the public attending Glasgow Science Museum were approached and asked if they would be willing to participate in a study ‘examining the link between perception and emotion’. No further details about the hypothesis were given. The FSQ cut-off points remained the same as the previous experiments. All other elements of the procedure and design remained the same as the previous experiments.

Results

When the participants were separated into moderate to high (n =19) and low (n = 27) spider fear using the FSQ, the groups differed significantly on the FSQ (U = .000, N_1 = 27, N_2 =19, p = .00) and depression (U = 167.500, N_1 = 27, N_2 =19, p = .05).

In contrast to the analyses for the previous two experiments, a multidimensional chi-square test with exact significance option revealed a significant effect between noticing categories and fear status (χ^2 = 9.916, df = 2, *p* = .01, ϕ = .46). Table 3 presents the noticing rates for both the moderate to high and low spider fear groups on the critical inattention trial.

< Insert table 3 about here >

Post-hoc comparisons on the noticing categories were then conducted for each of the fear groups separately. The low spider fear group revealed a significant effect (χ^2 = 8.222, df = 2, *p* = .02). Follow-up analyses for this group were conducted on the comparison of interest, between the inattentionally blind and identifier participants and this was also significant (χ^2 = 4.545, df = 1, p = .03), reflecting the greater rate of inattentional blindness for this group.

Comparisons of the noticing categories were also conducted for the moderate to high spider fear group. A chi-square test revealed an overall significant effect in this case as well (χ^2 = 11.789, df = 2, *p* = .00). Follow-up analyses were conducted between the inattentionally blind and identifier groups and revealed a marginally significant effect (χ^2 = 3.556, df = 1, p = .06), reflecting the greater "identifier" rates for this group.

Discussion

The results from experiment three present a different picture to the previous experiments. The analysis revealed a significant effect between fear status and noticing categories. The follow-up analysis of interest was between the inattentionally blind and identifier participants. In the case of the low fear group, significantly more of the participants were inattentionally blind. In the case of the moderate to high fear group, this pattern was reversed. Specifically, more of the participants in this group noticed, and were able to correctly identify, the unexpected spider image. Although the analysis of interest in the moderate to high fear group only approached significance, the overall pattern of results supports the hypothesis that increased spider fear will lead to the rapid identification of spiders appearing in the left visual field (left quadrant of the cross) during an inattentional blindness task. Conversely, the results from the low fear group suggest that spiders will be bypassed by the attentional system if they are not perceived as particularly threatening.

General Discussion

The purpose of the current series of experiments was to examine whether individuals with elevated fear of spiders notice spiders in a rapid experimental task where the spiders are presented against expectation. An additional purpose was to examine specifically the roles of the left and right cerebral hemispheres in threat detection. The confirmation of an attentional bias, mediated by the right cerebral hemisphere in experiment three is an important finding because previous methods used to explore such attentional biases have lacked specificity to the attentional system (i.e., the Stroop task; Williams et al., 1997), have been imprecise regarding the components of visual attention (i.e., as in the probe-detection task; Fox et al., 2001), or have lacked specificity to particular cerebral hemispheres. Additionally, no previous methods have examined attentional response to *threatening and unexpected* stimuli. The results from the first two experiments failed to confirm the hypothesis that elevated fear of spiders causes the rapid engagement of spider stimuli. However, in the case of the first experiment, it is possible that the size of the stimulus was not sufficient to have an effect. Nevertheless in the case of the second experiment, where the size of the stimulus was increased, a rapid engagement bias for spider images was still not found. In experiment 3, the spider stimulus was moved to the left visual field (left quadrant of the cross) on the grounds of evidence of hemispheric biases in different species (Cantalupo et al., 1995; Koboroff et al., 2008; Quaranta et al., 2011; Rogers, 1997, 2000; Rogers et al., 2004; Roso Salva et al., 2012; Siniscalchi et al., 2010) and some evidence indicating this might be the case in anxiety disorders (Fox, 2002; Mogg & Bradley, 2002). In this case, the results do support the hypothesis that elevated spider fear causes the rapid engagement of spiders when they are presented against expectation and appear in the left visual field.

This finding of hemispheric asymmetry is supportive of prior evidence that attentional biases to threat are more pronounced in the right hemisphere (Fox, 2002; Mogg and Bradley, 2002). These results are consistent with suggestions that the right hemisphere may be more vigilant in general than the left (Arruda et al., 1999), more responsive to stressors, particularly after stressful events (Adamec, 2003), and shows greater activation than the left hemisphere to threatening stimuli both in other species, including birds (e.g., Koboroff et al., 2008; Rogers, 1997, 2000; Rogers et al., 2004), rats (Rogers, 1997), fish (Cantalupo et al., 1995) and dogs (Quaranta et al., 2011; Siniscalchi et al., 2010; Siniscalchi et al., 2011) and in human anxiety states (Fox, 2002; Mogg & Bradley, 2002). Additionally, the right hemisphere may be more involved in negative emotional arousal at both the subcortical and cortical levels (Davidson, 2002; Gainotti, 1972; Moses, Houck, Martin, Hanlon, et al., 2007).

This result has methodological implications for the need to explore both left and right visual fields in assessing response to phobic stimuli. More importantly however, such findings are of value to understanding the way in which the attentional systems operate in the brain. Firstly, evidence suggests that the left eye (right hemisphere) may have be specialised for more global processing (Rogers 2000). In terms of the current findings, it may be the case that spiders need to be processed globally in order to induce a rapid fear based response. Secondly, the results are important because they demonstrate that even fear-inducing stimuli do not necessarily capture both hemispheres during the initial engagement of attention. It is of interest that hemispheric division of labour can occur even under conditions of perceived threat.

The findings from experiment 3 are more likely to reflect biases in the initial *engage* component of attention than results from other paradigms such as probe-detection tasks, which typically have longer SOAs of 500ms. Such studies may be better conceptualised as reflecting biases in the *disengage* component of visual attention because they permit the switching of attentional resources between stimuli (Field & Cox, 2008; Fox et al., 2001). In contrast, the results from experiment 3 with SOAs of 200ms support those presented by Mogg and Bradley (2006; experiment 1), who found an attentional bias to spiders in a probe detection task with an SOA of 200ms, more indicative of the engage component of attention. The present results extend our knowledge of attentional biases in spider fear beyond this prior evidence. The short presentation time, the lack of task relevancy of the spider image, and its covert presentation, reduces the possibility that the participants were controlling their visual processing resources towards the stimulus. As such, the method is more likely to reflect bottom-up processes, providing greater certainty that detection of the spider image in the group with elevated spider fear was due to the engage component of visual attention.

The findings from the current study also extend the findings from visual search tasks of the kind employed by Miltner et al. (2004) where mushrooms were the target object and spiders the distractors. Presenting a spider at the same time as the target mushroom caused the spider-fearful participants to orient their gaze to the spider before they located the mushroom, suggesting a particular sensitivity to the spiders. However in other conditions, the spider was the target stimulus and so was task-relevant, which may have influenced expectation. The current series of experiments extend the findings of such studies by employing the inattentional blindness paradigm to minimize expectation. The fearful participants in experiment 3 identified the spider even though there was no reason for them to believe that one would be present.

In minimizing expectation, the inattentional blindness paradigm provides greater ecological validity than other procedures for assessing attentional bias to phobic stimuli such as spiders. Future assessments of attentional bias to spiders could however increase ecological validity even further by employing moving fearful images in dynamic inattentional blindness tasks (e.g., Simons & Chabris, 1999).

One point of interest with the current results is that the third experiment differs from the previous two in that the participants with elevated spider fear also showed higher depression scores on the HAD scale. Cognitive models of depression and anxiety suggest that they have different effects on the cognitive system. Anxiety is suggested to result in an "outward focus", influencing processing in the perceptual and attentional systems and resulting in increased vigilance for threat. Depression on the other hand is suggested to have an "inward focus", resulting, for example, in greater recall of negative memories. Clinical evidence suggests that depression and anxiety have a high co-morbidity and this may account for the current findings (Williams et al., 1998).

To summarise, the results from the present study overcome interpretation difficulties associated with other methods for assessing attention to feared stimuli. In particular, the rapid presentation times and covert presentation of the spider stimulus allow for assessment of the engage component of visual attention. The current results suggest that under these conditions, people with an elevated fear of spiders will rapidly detect them even when not expected, provided that the spiders appear in the left visual field and so are initially presented to the right hemisphere.

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Table 1. Noticing rates for the low and moderate to high fear groups on the inattention trial for experiment 1.

	Response Type		
Fear of spiders	Inattentionally blind	Detector	Identifier
Low fear of spiders	21 (57%)	6 (16%)	10 (27%)
Moderate to high fear of spiders	7 (41%)	7 (41%)	3 (18%)

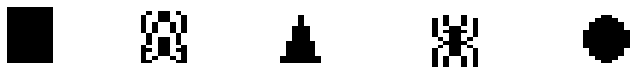
Table 2. Noticing rates for the low and moderate to high fear groups on the inattention trial for experiment 2.

	Response Type		
Spider fear	Inattentionally blind	Detector	Identifier
Low fear of spiders	18 (50%)	9 (25%)	9 (25%)
Moderate to high fear of spiders	8 (62%)	1 (8%)	4 (30%)

Table 3. Noticing rates for the low and moderate to high fear groups on the inattention trial for experiment 3.

	Response Type		
Spider fear			
	Inattentionally blind	Detector	Identifier
Low spider fear	16 (59%)	5 (19%)	6 (22%)
Moderate to high spider fear	5 (26%)	1 (5%)	13 (68%)

Figure 1. Force choice test including the spider image included in the experiment on the critical inattention, divided attention and full attention trials.



Appendix A. The Fear of Spiders Questionnaire (FSQ).

Fear of Spiders Questionnaire

This questionnaire is designed to assess your fear of spiders. Please read it carefully and **respond to all questions.**

1 = not like me; 7 = more like me.

1	If I came across a spider now, I would get help from someone else to remove it.	1	2	3	4	5	6	7
2	Currently, I am sometimes on the look out for spiders.	1	2	3	4	5	6	7
3	If I saw a spider now, I would think it will harm me.	1	2	3	4	5	6	7
4	I now think a lot about spiders	1	2	3	4	5	6	7
5	I would be somewhat afraid to enter a room now, where I have seen a spider before.	1	2	3	4	5	6	7
6	I now would do anything to try and avoid a spider	1	2	3	4	5	6	7
7	Currently, I sometimes think about getting bit by a spider	1	2	3	4	5	6	7
8	If I encountered a spider now, I wouldn't be able to deal effectively with it.	1	2	3	4	5	6	7
9	If I encountered a spider now, it would take a long time to get it out of my mind,	1	2	3	4	5	6	7
10	If I came across a spider now, I would leave the room	1	2	3	4	5	6	7
11	If I saw a spider now, I would think it would try to jump on me.	1	2	3	4	5	6	7
12	If I saw a spider now, I would ask someone else to kill it.	1	2	3	4	5	6	7
13	If I encountered a spider now, I would have images of it trying to get me.	1	2	3	4	5	6	7
14	If I saw a spider now, I would be afraid of it.	1	2	3	4	5	6	7
15	If I saw a spider now, I would feel very panicky.	1	2	3	4	5	6	7
16	Spiders are one of my worst fears.	1	2	3	4	5	6	7
17	Would feel very y nervous if I saw a spider now.	1	2	3	4	5	6	7
18	If I saw a spider now, I would probably break out in a sweat and my heart would beat faster.	1	2	3	4	5	6	7

Appendix B. The depression subscale of the Hospital Anxiety and Depression (HAD) Scale.

1. I feel cheerful: Most of the time ☐ A lot of the time ☐ Time to time, occasionally ☐ Not at all ☐	**2. I have lost interest in my appearance:** Not at all ☐ Not often ☐ Sometimes ☐ Most of the time ☐
3. I feel as if I am slowed down: Nearly all of the time ☐ Very often ☐ Sometimes ☐ Not at all ☐	**4. I look forward to things with enjoyment:** As much as I ever did ☐ Rather less than I used to ☐ Definitely less than I used to ☐ Hardly at all ☐
5. I still enjoy the things I used to enjoy: Definitely as much ☐ Not quite so much now ☐ Only a little ☐ Hardly at all ☐	**6. I can laugh and see the funny side of things:** As much as I always could ☐ Not quite so much now ☐ Definitely not so much now ☐ Not at all now ☐
7. I can enjoy a good book or radio or TV programme: Often ☐ Sometimes ☐ Not often ☐ Very seldom ☐	

[1] Across the three experiments presented here, all of the participants noticed the spider image on the full attention stages of the experiments.