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Fear-object perception: does it entail the involuntary capture of attention?

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ABSTRACT

The idea that fearful stimuli are automatically detected i.e. without attention, is challenged by the hypothesis that detection of threatening stimuli is facilitated by the involuntary, stimulus-driven recruitment of attentional resources. In order to clarify this question, we studied spiders detection in arachnophobic individuals by means of an iconic version of the Attentional Blink Task (AB).

The experiment consisted of two tasks: 1) Probe detection within a rapid sequence of distractors, including a Critical Distractor (CD); 2) Probe detection and identification of the CD (Target). In this case, the close temporal proximity of CD-Target and Probe typically produces the so-called AB effect, that is the decrease of Probe visibility, due to competition for limited attentional resources. In both tasks, CD-Target was either a spider (50%) or an innocuous animal shape (50%), and Probe (a rabbit icon) was presented at one out of 3 possible lags from the CD-Target.

At lag I (100 ms), arachnophobics, at difference with controls, exhibited an AB effect also when the spider was the CD to be ignored. Moreover, Probe detection scores were inversely correlated with spider recalls at lag I. In conclusion, our findings contrast the automatic view of threat detection, and support an attention capturing mechanism automatically driven by the fearful connotation of the stimulus.

Key words

Fear • Automatic Detection • Attention Capture • Animal Phobia Model • Attentional Blink Task • Humans

Introduction

A great amount of research on fear has mainly focused on the "automatic" or "pre-attentive" mechanisms of threat detection (LeDoux, 1998; Ohman and Mineka, 2001). Based on several neurophysiological findings (Morris et al., 1998; Vuilleumier et al., 2001), the central idea of this hypothesis is that some limbic brain structures, such as amygdala, respond to threat independently from top-down factors, i.e. attention, awareness or task instructions, producing an automatic behavioral module (Mathews and MacLeod, 1985; Watts et al., 1986; McNally et al., 1990; Ohman and Soares, 1993, 1994; Van den Hout et al., 2000; Ohman et al., 2001; Ruiz-Padial et al., 2005; Blanchette, 2006). In contrast with the "automatic" view, some authors suggest that full threat evaluation requires an adequate amount of attentional resources (Compton, 2003; Pessoa, 2005; Straube et al., 2006), and that attention modulates amygdala activity during emotional processing (Pessoa et al., 2002). In particular, it has been claimed (Varela and Depraz, 2000; Lambie and Marcel, 2002) that emotion consists of the selective and enhanced awareness of some events rather than an unconscious/automatic state. When we are frightened, the objects of the environment appear with differential priorities of action and perception and, to shape the subjective perceptual awareness, emotion requires a peculiar deployment of attention, since

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it is attention itself that assigns priorities to events. It is known that highly supraliminal stimuli can be neglected if the subject's attention is at that moment unavailable or differently engaged (Shapiro et al., 1997a; Enns and Di Lollo, 2000; Kim and Blake, 2005). The Attentional Blink (AB) effect offers a typical evidence of such a temporary functional blindness. The AB effect refers to the failure to detect a second salient target (Probe) presented after a first target within a rapid sequence of visual stimuli occurring at the same spatial location (Rapid Serial Visual Presentations, RSVP) (Raymond et al., 1992; Chun and Potter, 1995; Shapiro et al., 1997a). Typically, Probe detection is reduced if it appears within 100-500 ms following the correct identification of the first target, and it is assumed that Probe visibility depends on the amount of attention that is available at the specific time lags from target.

Probe stimuli are differentially resistant to the AB effect. For instance, detection of affective probes, such as emotional words (Keil and Ihssen, 2004; Anderson, 2005), emotional faces (Mack et al., 2002; Fox et al., 2005) and the personal own name (Shapiro et al., 1997b) is found less impaired than detection of non emotional probes. The AB effect can be attenuated also by perceptual factors that increase uniqueness of the probes (Chun and Potter, 1995; Raymond et al., 1995). Thus, it has been suggested that the arousal and/or valence dimension of stimuli may reduce the threshold for perceptual awareness (Anderson, 2005).

In a recent study, Trippe et al. (2007) showed that the use of spider pictures as Probes attenuated the AB effect in arachnophobic subjects. In addition, the enhancement of P300, concomitant to the facilitation of spider pictures detection, was found. Similarly, in a recent study of ours (D'Alessandro et al., 2009), with animals shapes as stimuli, we found a significant reduction of the AB effect in aracnophobic individuals, specific to spider-probe detection. Thus, in phobics the conscious perception of the phobic object appears largely preserved even when most of their attentional resources are not available.

It can be speculated that spider-related images/ words could be less attention demanding for arachnophobics than for controls because of phobics enhanced capacity of identification of threat induced by the rapid amygdala activation of visual areas or by a noradrenergic-mediated arousal reaction that increases the responsiveness of the cortical output (Castellani et al., 2007).

Otherwise, perception of the feared object may be facilitated by an involuntary, stimulus-driven recruitment of attentive resources referred to as Attentional Capture (Yantis and Egeth, 1999; Simons, 2000). Indeed, there is evidence that meaningful objects, such as a smiling face or the subject's own name, are able to draw the attention even when they are unattended and task-irrelevant (Mack et al., 2002).

In order to clarify this issue, in the present experiment arachnophobic and non phobic control individuals were required to detect a neutral Probe – a rabbit's icon – while a spider or an innocuous animal icon was either a Critical Distractor to be ignored or a Target to be identified.

According to the automatic/pre-attentive view, when the spider is the distractor to be ignored, we would expect in arachnophobics the same effect as with no-spider CDs, that is no effects on Probe perception. In fact, if phobics automatically detect the spider, this occurs at no/low attentional costs and thus without affecting the successive Probe detection. Moreover, in arachnophobics, if detection of the spider (phobic object) impose no attentional load – at difference with the other innocuous animals that needs attention to be identified – we would expect no competition for attentional resources between Target and Probe and thus a reduction or even the total disappearing of the AB effect when the spider is the Target.

On the other hand, if perception of the feared object is facilitated by the involuntary stimulus-driven recruitment of attention (Attentional Capture hypothesis) we would expect that, in arachnophobics, when the spider is the Critical Distractor, spider detection could impose an attentional load capable of reducing Probe detection by means of a sort of AB-like effect.

Methods

Subjects

Volunteers were recruited from a group of 190 students at the University of Pisa. The Italian version of the Spider Phobia Questionnaire (SPQ) (Klorman et al., 1974) was used to rate the aversion to spiders of each subject. Fifteen individuals (2 males, 13 females), with scores higher than 20,

corresponding to the 90° percentile of the sample's scores distribution (Fig. 1), were assigned to the group of Arachnophobics; a psychiatrist assessed the presence in these subjects of specific phobia for spiders, according to the DSM-IV, American Psychiatric Association (APA), 2000. The Control group was formed by 15 subjects (2 males, 13 females) that scored lower than 10 to the Spider Phobia Questionnaire (60° percentile of the sample's distribution, Fig. 1). All the subjects were drug free, had normal or corrected-to-normal vision and did not present medical, neurological or psychiatric disorders, apart from phobia.
All participants signed an informed consent approved by a local Ethical Committee.

Stimuli and procedure

Visual stimuli and experimental paradigm are shown in Fig. 2 and 3.
Experiment was run on a FreeBSD PC system (Imago program, feanor.sssup. it/~pv/). Stimuli were projected for 70 ms in the centre of a screen placed at 57 cm from the eyes of the subject so that each image (figure + background) covered an area of 4° x 4°. The inter-stimulus interval (ISI) was set at 30 ms to obtain a frequency of presentation of 10 image/sec. An acoustic warning cue and the simultaneous appearing of a fixation point in the centre of the screen signalled the start of the stimuli presentation. Each array of stimuli included the Distractors, the Critical Distractor/Target and the Probe.

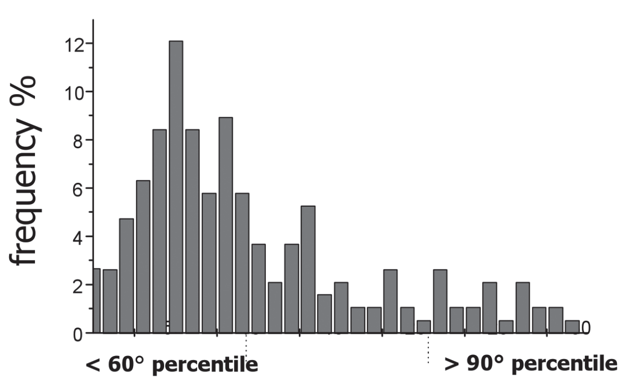

Fig. 1. - Frequency distribution of the Spider Phobia Questionnaire scores in the sample of 190 students participating to the study. The Arachnophobics group consists of individuals with scores higher than 20, corresponding to the 90° percentile of the sample's scores distribution; the Control group consists of individuals with scores lower than 10, corresponding to the 60° percentile of the sample's scores distribution.

Two sessions were performed according to different task conditions.
Each session included 10 training trials followed by one block of 90 experimental trials.
In one session (Simple Task) the participants were required to attend the appearance of a Probe (rabbit icon) while ignoring all the other stimuli, included a Critical Distractor (CD), i.e. a black animal shape presented on a yellow background. In half of the trials, CDs consisted of Spider icons while in the other half they were animal shapes randomly selected from a collection of Distractors that consisted of the black outlines of 24 innocuous animals. Probe was presented after CD at 3 different lags corresponding to latencies of 100 (lag I), 300 (lag III) and 500 ms (lag V). Thirty catch trials were also included so that a total of 90 sequences, produced in a randomised order, were presented at each participant. After the end of each experimental block, each subject was given a forced-choice memory recall test in which he/she was asked to recall as soon as possible how many trials included a colored stimulus and how many a spider shape, by choosing one of the follow percentage values: 0, 30, 50, 70, 100.
In the other session (Conditional Task), subjects were instructed to identify the CD-Target and detect the following Probe. Probes were presented at the same lag as in the first task. As in the previous task, in half of the cases CD-Target consisted of Spider shapes while in the other half of non-phobic animals. In both conditions subjects were instructed to respond verbally at the end of each sequence trying to report their visual experience as more accurately as possible, avoiding any guess on the presence of Probe and/or the identity of CD-Target.
The order of the two session was balanced among the subjects.

Data analysis

In the Simple Task the percentage of correct detection of each Probe in each of the three Lag (lag I, lag III, lag V) was calculated for each participant. In the Conditional Task, for each subject, the percentage of correct detection of each Probe was calculated for each lag with respect to the number of trials in which the Target was correctly identified. All the trials in which Target identification was incorrect were excluded. For analysis, percentage data were arcsine transformed according to the Anscombe formula (Anscombe, 1948). Percentages of correct Probe

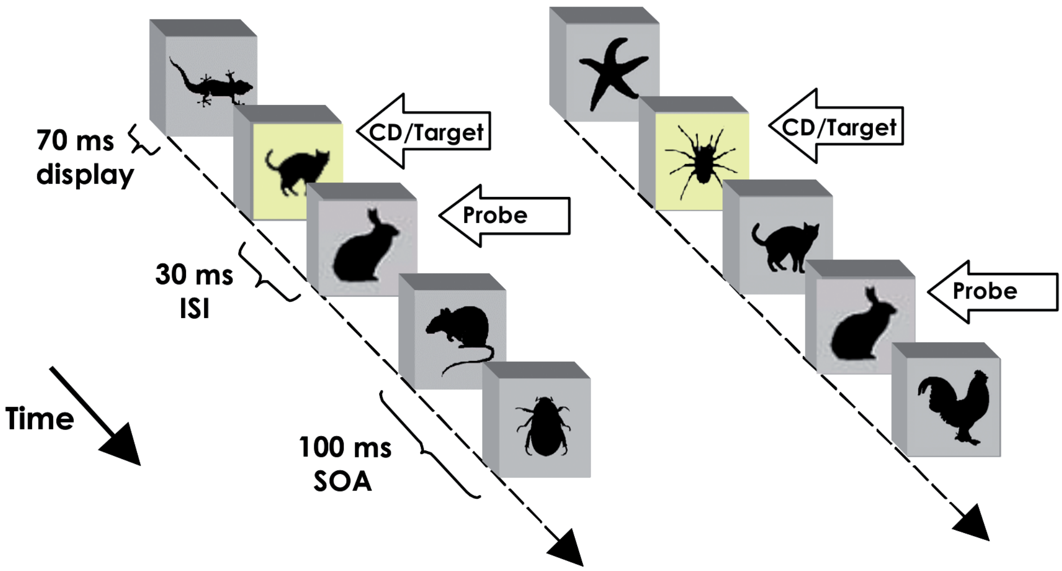

Fig. 2. - Schematic representation of stimuli and temporal parameters.

detections and errors were calculated and arcsine transformed.

Transformed data were then analyzed separately for CD/Target types (Spider and Neutral animal), through Repeated Measures ANOVA with Lag (lag I, lag III, lag V) and Task (simple and conditional) as Within Subjects factors and Phobia (Phobics and Controls) as Between Subjects factor.

In addition, within each group of subjects Probe detections scores obtained with the two CD/Target types were compared in the Simple and Conditional Task, separately, by means of paired t-tests.

As for memory recall test data, for each group mean percent recall of colored stimuli and spiders were calculated. Arcsin transformed data were then analyzed by means of one-way ANOVA.

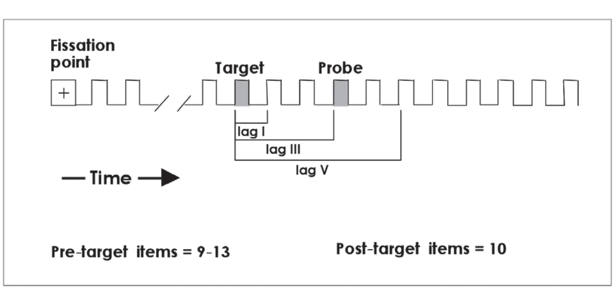

Fig. 3. - Flow Chart of the Attentional Blink paradigm.

In each subject, a non-parametric bivariate correlation analysis was also performed between the percentage of probe detection at lag I and the percentage of recalls of colored stimuli and of spiders, respectively.

Results

Spider Critical Distractor/Target

As shown in Fig. 4A, in the Conditional Task the two groups exhibited a typical AB effect with both Target types (spider and no-spider). However, in the Simple Task, when the Spider's icon was the CD to ignore, Phobics and Controls performances were different.

Statistical analysis yielded significant Task ($F(2,28) = 36.71$, $p = 0.0001$), Lag ($F(2,56) = 32.08$, $p = 0.0001$) and Task x Lag effects ($F(2,56) = 39.80$, $p = 0.0001$), with significant differences between Lags (I < III, $F(1,28) = 28.88$, $p < 0.0001$; III < V, $F(1,28) = 57.89$, $p < 0.0001$) in the Conditional Task, confirming the occurrence of the typical AB effect.

In addition, significant Phobia ($F(1,28) = 5.02$, $p = 0.03$) and Lag x Phobia ($F(2,56) = 4.38$, $p = 0.017$)

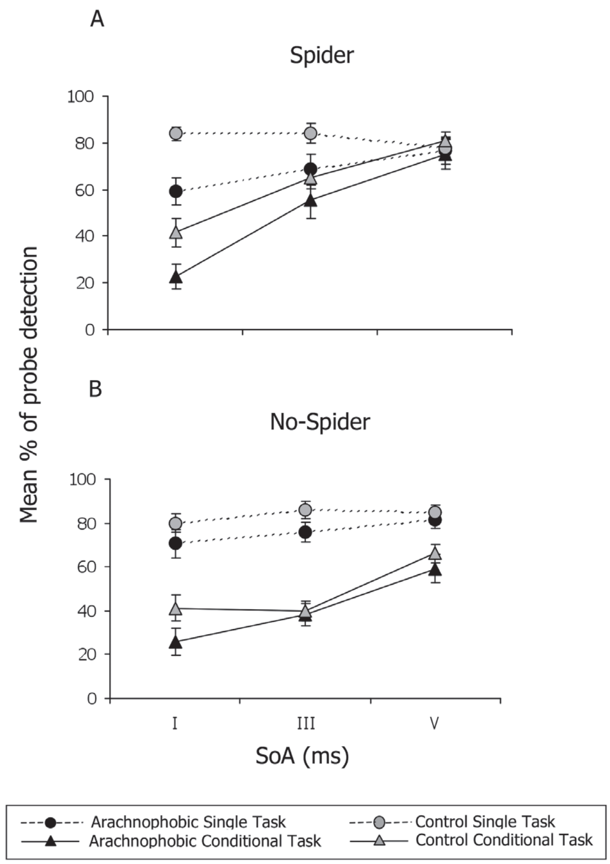

Fig. 4. - Mean percentage (± SEM) of Probe detections scored by Arachnophobics and Controls in the Single and Conditional Tasks with the Spider (A) and No-spider (B) CD/Target.

effects were found indicating Between Subjects differences in Probe detection across lags. In fact, within Phobics, Lag effect was highly significant ($F(2,28) = 30.51$, $p = 0.0001$), with Probe detection scores significantly different across the various lags (I < III, ($F(1,14) = 20.75$, $p = 0.0001$; I < V, ($F(1,14) = 8.43$, $p = 0.012$), while in Controls, in spite of a significant Lag effect ($F(1.8,25.2) = 6.43$, $p = 0.007$), differences were found only between lag I and III ($F(1,14) = 8.19$, $p = 0.013$). Further post-hoc Within Subjects comparisons performed in the Simple and Conditional Task, separately, showed that the Lag effect was present in the Conditional Task in both Phobics ($F(2,28)$ 35,97, $p < 0.001$; I < III $F(1,14)$ 29.26, $p < 0.001$; III < V $F(1,14)$ 42.10, $p < 0.001$) and Controls ($F(2,28)$ 16.68, $p < 0.001$; I < III $F(1,14)$ 13,01, $p = 0.003$; III < V $F(1,14)$ 19.51, $p < 0.001$) while in the Simple Task it was found in Phobics, only ($F(2,28)$ 7.78, $p = 0.002$, I < III, $F(1,14)$ 4.87, $p = 0.04$; III < V, $F(1,14)$ 10.72, $p = 0.006$).

In addition, Phobics scores were significantly lower than Controls at lag I (one-way ANOVA, $F(1,28) = 14.47$, $p = 0.001$) in both single (Phobics < Controls, ($F(1,28) = 14.83$, $p = 0.001$), and conditional tasks (Phobics < Controls, $F(1,28) = 6.54$, $p = 0.016$). An almost-significant difference between Phobics and Controls was also found at lag III during the simple task ($F(1,28) = 3.67$, $p = 0.066$).

Neutral Critical Distractor/Target

As shown in Fig. 4B when CD/Target was a Neutral animal icon, the performance in the two groups was quite similar. In fact, no Phobia effect or interactions were found.

ANOVA yielded significant Task ($F(1,28) = 143.45$, $p < 0.001$), and Lag ($F(2,56) = 22.06$, $p < 0.001$) effects as well as Task x Lag interaction ($F(2,56) = 9.93$, $p < 0.001$), with significant differences between Lags (I < V, $F(1,28) = 39.11$, $p < 0.001$; III < V, $F(1,28) = 53.02$, $p < 0.001$) in the Conditional Task, confirming the occurrence of the typical AB effect. Further post-hoc Within Subjects comparisons performed in the Simple and Conditional Task, separately, showed that the Lag effect in the Conditional Task was present in both Phobics ($F(2,28)$ 19.39, $p < 0.001$; I < III, $F(1,14)$ 6.21, $p = 0.026$; III < V, $F(1,14)$ 32.29, $p < 0.001$) and Controls ($F(2,28)$ 10.92, $p < 0.001$; I < V, $F(1,14)$ 11.88, $p = 0.004$; III < V, $F(1,14)$ 20.69, $p < 0.001$). In the Simple Task, no Lag effects were found in any of the two groups.

Spider vs. Neutral Critical Distractor/Target

As concern the Simple Task, we found no significant differences in the Control group between Spider and Neutral CDs at none of the three lags, while in the Phobic group there was a significant difference between Spider and Neutral CDs at lag I, with lower Probe detection scores with Spiders than with Neutral CDs ($t(14) = -2.23$, $p = 0.043$).

As for the Conditional Task, in both groups there was no significant difference between Spider and Neutral Targets at lag I as well as significant differences between the two target types at lag III and V.(Phobics: lag III, $t(14)$ 2.09, $p = 0.05$; lag V, $t(14)$ 3.43, $p = 0.004$. Controls: lag III, $t(14)$ 6.12, $p < 0.001$; lag V, $t(14)$ 4.88, $p < 0.001$).

Memory recall test

Explicit assessment of attentional capture induced by the appearance of critical distractors have been retrospectively obtained by a forced-choice recall test.

As shown in Fig. 5 both groups of subjects recalled a quite similar percentage of coloured stimuli, suggesting a uniform effect of color in drawing attention. Instead mean percent recall of spiders was significantly higher in arachnophobics (32%) with respect to controls (11%) ($F(1,28) = 5.91$, $p = 0.022$). This significant difference could be reliably accounted for by a differential capture of attention by spider in the two groups.

As concerns the non-parametric bivariate correlation analysis, no significant correlation (Spearman's rho(30) = -0.06, $p = 0.75$) was found between the percentages of Probe perception at lag I and the percent recalls of coloured stimuli (Fig. 6A). Instead, percentages of Probe perception at lag I were negative correlated with the percentages of spider recalls (Spearman's rho(30) = -0.817, $p < 0.001$) (Fig. 6B). This means that subjects with higher spider recalls performed reliably a lower Probe detection at lag I.

Discussion

The main result of the present study was that arachnophobic individuals showed a decreased accuracy in Probe detection when it appeared shortly after the spider icon. Unlike Controls, and at difference with neutral animal icons, lower scores in Probe detection occurred in Phobics also when the spider was the distractor to be ignored and they were explicitly required to focus their attention on the stimulus-Probe only. This effect, significant at lag I, was also associated with an enhanced recall of the spider-distractor.

These findings suggest an attentional capture-induced blink effect (Maki and Mebane, 2006) due to the contingent capture of attention by a preceding critical distractor. The notion that colored targets/ distractors are able to automatically attract attention is widely acknowledged (Folk et al., 2002; Snowden, 2002; Maki et al., 2003; Maki and Mebane, 2006). However, our results with the colored no-spider icons suggest that attention drawn by color is not sufficient *per se* to produce an AB effect. In fact, as suggested by Maki and Mebane (2006), the AB effect would occur only to the extent that the distractor is task relevant. Our results extend this idea as we

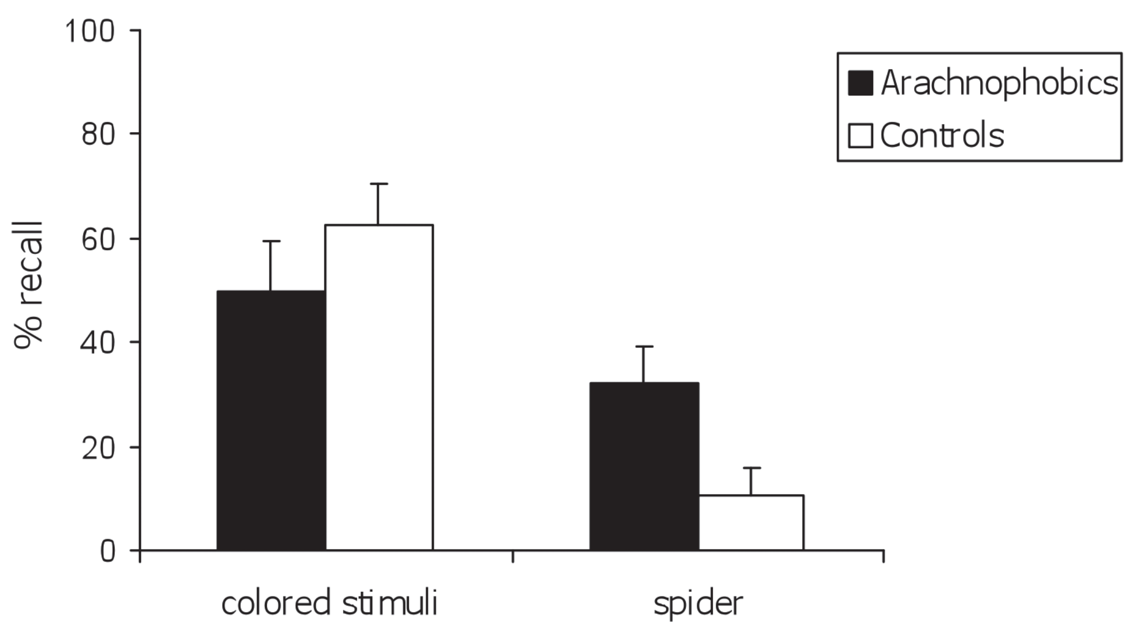

Fig. 5. - Mean percent recall of coloured distractors and spiders in Control and Arachnophobic subjects.

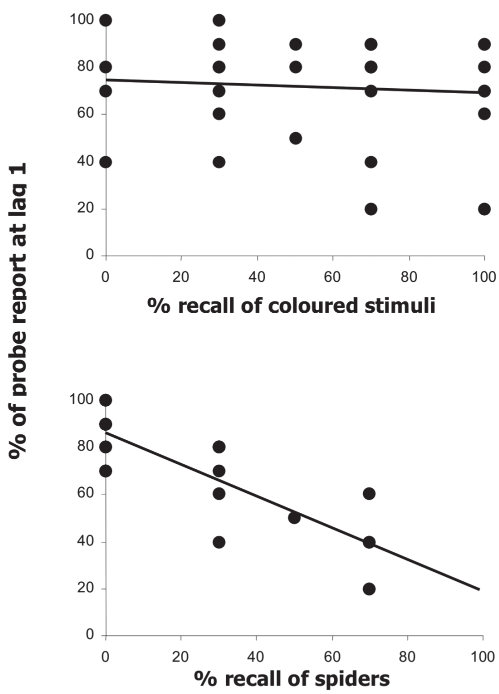

Fig. 6. - Bivariate correlation between percentages of probe perception at lag I and the percent recalls of coloured stimuli (top panel) and spiders (bottom panel). The linear trend line is shown.

showed that an emotional distractor, such as the phobic object, can produce an AB even when the distractor and probe do not share any task-relevant feature. A strong definition of Attentional Capture requires that subjects have no expectancy about the critical distractor (Simons, 2000). In this respect, it could be argued that arachnophobic could have voluntary directed their attention to the highlighted distractor, according to a strategic tendency to scan their environment seeking for spiders (Thorpe and Salkovskis, 1999; Pflugshaupt et al., 2005). Our results are not consistent with this account; in fact, distractors recall data (Fig. 5) showed that Phobics did not pay more attention than Controls to the coloured icons; also, if they were voluntarily searching for spiders during the entire task, they would have shown a poor Probe detection performance also with the neutral Critical Distractor. Since this was not the case, then, we can consistently assume that the fear-related distractor captured Phobics in a passive bottom-up manner.
Another important result is that both Arachnophobics and Controls exhibited a typical AB effect when the spider was the Target. As indicated by the amplitude of AB, identification of spider Target did not drained in Phobics less attentional resources than in Controls; On the contrary, in Phobics Probe detection was greatly impaired by the previous attentional engagement on the feared object; this effect was particularly evident at lag1 where Phobics were even more impaired than Controls.
This finding allows us to reject the "automatic" mechanisms of threat detection (LeDoux, 1998; Ohman and Mineka, 2001) that is based on the hypothesis of a full fear evaluation independent from top-down factors. In fact, our data show how perceptual awareness of feared object requires an adequate deployment of attentional resources that is sufficient to produce a subsequent AB effect.
This study is in accord with several data from dot-probe studies on spider-phobic individuals, which have been interpreted as evidence for enhanced engagement of attention to threat cues (Mathews and McLeod, 2005). As shown in those experiments, arachnophobic participants responded faster than non phobic controls to dots presented at the location of a previously shown spider picture, and this was interpreted (Mogg and Bradley, 2006) as an attentional bias for spider stimuli. Similar findings were described in a free-viewing task (Rinck and Becker, 2006) in which first fixation of spider-fearful subjects was more often on spider pictures than on no-spider ones.
In spite of these evidence, some authors still question the relevance of initial attentional capture by fear-relevant stimuli suggesting a less specific attentional bias extended to other animals independent of how much they elicit fear (Lipp et al., 2004; Lipp, 2006). Our data contrast with this hypothesis by showing that the decreased performance in Probe detection was specific to the condition with spider icons.
It is worth noting that recent eye-tracking studies on spider-phobic patient did not show an initial capture of attention when fear-relevant stimuli were task-relevant (Rinck et al., 2005). Interestingly, more robust findings for an attentional bias were found when fear-relevant stimuli were, as in our experiment, task irrelevant distractors (Miltner et al., 2004). It has been suggested that phobic material would distract from ongoing task execution due to either enhanced engagement of attention or slowed down disengagement of attention from phobic stimuli (Rinck and Becker, 2006; Gerdes et al., 2008). So far, the question is open even though recent findings suggest that spider-phobic patients fail to disengage attention from spiders (Gerdes et al., 2008). Our

findings do not allow to distinguish between the two possibilities, since Probe detection decrease could be explained by both mechanisms.

Conclusions

Altogether these results suggest that:

– The fear salience of a stimulus enhances its probability to be consciously perceived.
– Detection of feared objects does not benefit from special "automatic" processing but rather depends on special control of attentional resources. Specifically, fear salience boosts the engagement and/or slows down the disengagement of attention, respectively, toward and from the feared object.
– The feared stimulus draws visual attention even when the subject is not required to attend it by means of an attention capture mechanism independent from executive voluntary control.

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