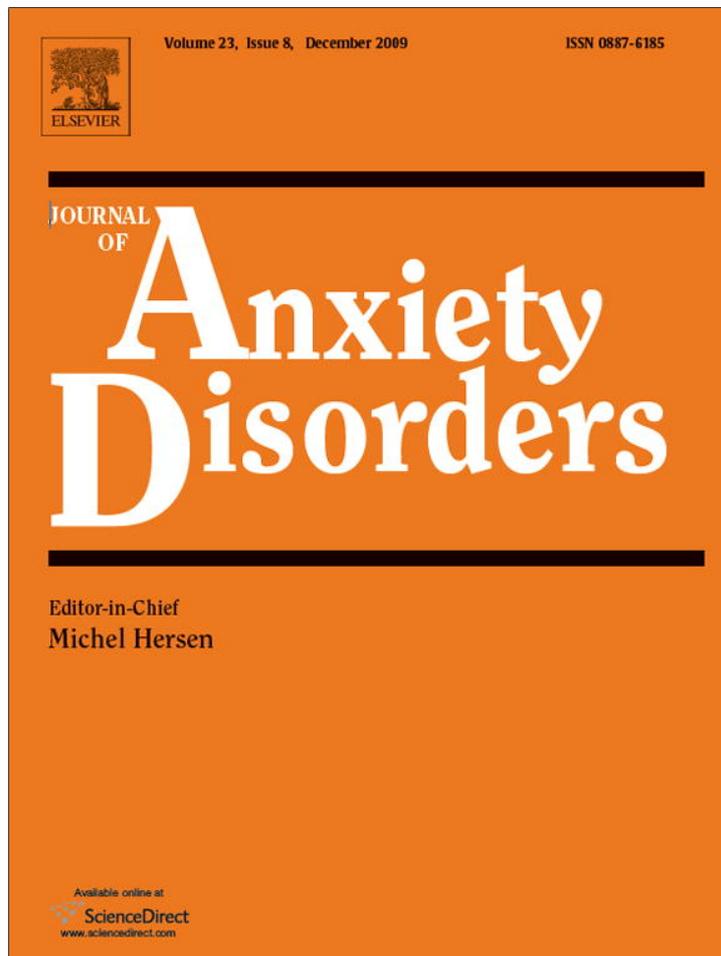


Provided for non-commercial research and education use.
Not for reproduction, distribution or commercial use.



This article appeared in a journal published by Elsevier. The attached copy is furnished to the author for internal non-commercial research and education use, including for instruction at the authors institution and sharing with colleagues.

Other uses, including reproduction and distribution, or selling or licensing copies, or posting to personal, institutional or third party websites are prohibited.

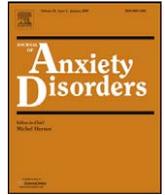
In most cases authors are permitted to post their version of the article (e.g. in Word or Tex form) to their personal website or institutional repository. Authors requiring further information regarding Elsevier's archiving and manuscript policies are encouraged to visit:

<http://www.elsevier.com/copyright>



Contents lists available at ScienceDirect

Journal of Anxiety Disorders



Selective visual working memory in fear of spiders: The role of automaticity and material-specificity

Andrea Reinecke^{a,*}, Eni S. Becker^b, Mike Rinck^b

^aDresden University of Technology, General Psychology, Zellescher Weg 17, 01062 Dresden, Germany

^bRadboud University Nijmegen, The Netherlands

ARTICLE INFO

Article history:

Received 17 July 2007

Received in revised form 1 July 2009

Accepted 2 July 2009

Keywords:

Attention

Visual working memory

Serial position effects

Fear of spiders

ABSTRACT

Following cognitive models of anxiety, biases occur if threat processing is automatic versus strategic. Therefore, most of these models predict attentional bias, but not explicit memory bias. We suggest dividing memory into the highly automatic working memory (WM) component versus long-term memory when investigating bias in anxiety. WM for threat has rarely been investigated although its main function is stimulus monitoring, particularly important in anxiety. We investigated WM for spiders in spider fearfuls (SFs) versus non-anxious controls (NACs). In Experiment 1 (23 SFs/24 NACs), we replicated an earlier WM study, reducing strategic processing options. This led to stronger group differences and, thus, clearer WM threat biases. There were no group differences in Experiment 2 (18 SFs/19 NACs), using snakes instead of spiders to test whether WM biases are material-specific. This article supports cognitive models of anxiety in that biases are more likely to occur when reducing strategic processing. However, it contradicts the assumption that explicit memory biases are not characteristic of anxiety.

© 2009 Elsevier Ltd. All rights reserved.

Imagine a spider phobic with whom you are chatting at a party detects a big, unhandsome spider. Do you think she or he can follow the conversation with the same enthusiasm as they did before the appearance of the spider? Although politely looking at you, she surely knows exactly where the spider was the last moment she attended to it, and she is surely able to tell if it has moved two inches since last inspected. It seems contradictory to expect that a phobic would, although having seen the spider, avoid its monitoring and the later memorization of the fearful situation.

Nevertheless, empirical evidence does not reflect our amateur impression of the relevance of monitoring and memory in anxiety. Indeed, research to date coherently suggests *attentional biases* in specific phobia and in other anxiety disorders, implying increased detection of threatening stimuli (Mathews & MacLeod, 2005). However, concerning the investigation of *memory bias*, there is currently little evidence for biased recall in specific phobia and most other anxiety disorders (as an exception, there is a multitude of evidence for explicit memory bias in panic disorder, Becker, Rinck, & Margraf, 1999; Lundh, Thulin, Czyzykow, & Oest, 1998). Some free-recall studies using word lists for encoding failed to detect enhanced recall of threat-related words in spider phobia (Kulas, Conger, & Smolin, 2003; Watts, 1986; Watts & Dagleish,

1991), other studies succeeded in finding better recall (Kindt & Brosschot, 1998; Rusted & Dighton, 1991). Even the use of ecologically valid materials such as pictures, real spiders, or video clips has led to conflicting reports (Thorpe & Salkovskis, 2000; Wessel & Merckelbach, 1997, 1998). Regarding other anxiety disorders, research results on emotional memory are similarly mixed (Coles & Heimberg, 2002).

Cognitive theories of anxiety (Beck, Emery, & Greenberg, 1985; Clark & Wells, 1995; Eysenck, 1992; Mathews & Mackintosh, 1998; Ohman & Mineka, 2001; Williams, Watts, MacLeod, & Mathews, 1997) provide a theoretical framework to improve comprehension of the circumstances under which cognitive biases occur and offer a rationale as to why they occur in a specific manner, helping us answer the question of how cognitive factors cause or maintain anxiety, and how cognitive therapeutic methods might be improved. These models coherently assume that *automaticity* of threat-information processing is the core factor in finding cognitive biases. Automatic processing is assumed to be very quick and inevitable, meaning that the process involuntarily takes place whenever a specific stimulus occurs (Posner & Snyder, 1975; Yonelinas & Jacoby, 1995). It can be caused exogenously by unexpected events, for instance a big spider jumping across the buffet. In contrast, strategic processing is endogenously (Jonides, 1981; Mueller & Rabbitt, 1989) activated under voluntary control of the individual, for instance when trying to speak to somebody at a party although having just detected that big spider. In line with their emphasis on the automaticity aspect, cognitive anxiety

* Corresponding author at: University of Oxford, Department of Psychiatry, Oxford OX3 7JX, United Kingdom.

E-mail address: andrea.reinecke@psych.ox.ac.uk (A. Reinecke).

models predict disorder-specific attentional biases in anxiety, caused by an automatic attraction of attention by the threat value of a stimulus (Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Williams et al., 1997). Memory biases are also expected as long as information processing is automatic-perceptual, rather than strategic-conceptual (Fox & Georgiou, 2004; Mathews & Mackintosh, 1998; Williams et al., 1997).

Keeping these postulations in mind when reviewing previous memory bias research, two potential methodological shortcomings become apparent. First, a broad range of these studies used verbal material instead of pictures (Kulas et al., 2003; Watts & Dalglish, 1991). Not only does it seem self-evident that pictures of feared objects make more impact than written words (Kindt & Brosschot, 1997), but presentation of word lists also enforces conceptual processing, which – following cognitive theories of anxiety – rules out the possibility of finding memory biases. Second, previous memory studies did not manipulate stimulus duration and retention intervals and, thus, automaticity of processing. In experimental psychology, there is wide agreement about understanding memory as roughly divided into at least two subsystems: working memory (WM) and long-term memory (Atkinson & Shiffrin, 1968; Baddeley, 1992; Luck & Vogel, 1997). Previous studies addressing memory bias measured some sort of *strategic long-term memory*, with stimulus presentation times of at least 1 s and retention intervals of 1 h or more. Therefore, if cognitive biases in anxiety indeed only occur when conceptual-strategic processing is ruled out, it is not surprising that no memory biases were found.

However, it is surprising that only very few studies subsequently focused on WM when testing for memory biases, as this component seems to reflect the more *automatic* level of memory and one would therefore expect to find preferences for threat material. Revisiting the case example at the beginning of this article, your spider-phobic conversation partner will instantly be able to move his/her attention back to the spider and tell whether it had moved or not. Basically, this is an example of high performance in a WM task, being so exceptional because of the threat value of the stimulus. And indeed, the few existing studies on WM performance in anxiety yielded promising results, reporting higher WM performance for spider pictures in spider fearfuls (SFs) compared to controls (Reinecke, Rinck, & Becker, 2006, 2008). The crucial methodological difference of WM tasks compared to previous memory tasks thereby lies in a very rapid serial visual stimulus presentation and an immediate cued recall, ruling out strategic encoding (e.g., by additionally using verbal WM, Baddeley, 1992). For instance, Reinecke et al.'s (2006) design involved the simultaneous presentation of 16 images per trial, one of these depicting a spider. On each trial, five of these images were cued one after another for WM encoding by increasing their background illumination for 150 ms. Memory was tested by masking one of these five images immediately after the cueing sequence and asking for its prior identity. In some cases, an uncued image was probed to test spontaneous memory for the remaining 11 items visible on the screen. Visual working memory (VWM) for cued spider images was enhanced in both SFs and controls. However, only SFs showed a memory advantage for *uncued* spiders, that is, spider images that were actually not relevant to the task.

Although the results of this study were clear-cut, there are several limitations to their interpretation. First, on each trial the matrix of 16 images was already visible during an *initial orientation time of 500 ms*, before the beginning of the cueing sequence. Considering the broad evidence for biased attention in anxiety (Mathews & MacLeod, 2005; Rinck & Becker, 2005; Williams et al., 1997) it is possible that the memory enhancement for uncued spiders in SFs occurred because these participants strategically searched for this item during the initial interval already. Moreover,

lack of group differences in memory for cued spiders may also be due to this long initial orientation time, as control participants may have used specific encoding strategies during this time to make up for any advantage that fearfuls might have. In any case, it is obvious that the initial interval of 500 ms leaves room for uncontrolled preprocessing of the presented items. Second, it could also be argued that fearfuls would show a VWM preference for any threatening image, not only for spiders. In fact, there is reason to expect that effects found for spiders in Reinecke et al. (2006) might also occur for other negative items, particularly for other threatening animals. For instance, Becker and Rinck (2004) found that spider phobics showed comparable effects for spiders and similar animals such as beetles. Surprisingly, this interpretational problem has been largely neglected in studies of attentional biases in spider phobia so far, as most experiments employed only one type of negative stimulus (Mogg & Bradley, 2006; Thorpe & Salkovskis, 1997). The few exceptions indeed show enhanced processing not only for phobic, but also for nonphobic, fear-relevant stimuli (Ohman, Flykt, & Esteves, 2001), particularly under conditions of unawareness and automaticity (Carlsson et al., 2004). To test the weight of these alternative explanations and potential limitations, two follow-up studies were designed. In Experiment 1 we replicated the design of Reinecke et al. (2006) with a shortened initial orientation time of 150 ms, in Experiment 2 the critical stimulus was a snake instead of a spider to test for material-specificity of the VWM effects found before.

1. Experiment 1: VWM for spiders in SFs

Given the evidence suggesting a quick attentional shift toward threatening stimuli (Ohman et al., 2001; Rinck & Becker, 2006; Rinck, Reinecke, Ellwart, Heuer, & Becker, 2005), we have to assume that in the experiment by Reinecke et al. (2006), several uncontrolled attentional processes occurred within the initial 500 ms initial orientation time. Therefore, we replicated the experiment, but shortened the initial orientation time from 500 to 150 ms. Pilot tests had shown that this was the shortest possible time at which participants did not miss the first item of the cueing sequence. If the advantage for *uncued* spiders in SFs was indeed based on processing of the spider image during the initial 500 ms, the advantage should be greatly reduced in Experiment 1. Consequently, SFs and non-anxious controls (NACs) should not differ regarding their memory accuracy for *uncued* items anymore. Moreover, the fact that the two groups showed comparable effects for *cued* items should remain unchanged. In sum, this alternative reasoning predicts that SFs and NACs will behave more similarly in Experiment 1 than in the experiment by Reinecke et al. (2006). In contrast, if the NACs instead of the SFs used the initial 500 ms interval to strategically process the spider image, the change to a 150-ms interval should selectively deteriorate performance of the NACs. In this case, Experiment 1 should yield higher memory accuracy in SFs than NACs even for *cued* spider items, for which Reinecke et al. (2006) had not found any difference between SFs and NACs. Thus, this line of reasoning leads to the prediction that the differences between SFs and NACs will increase in Experiment 1 compared to the experiment of Reinecke et al. (2006).

In order to test these alternative lines of reasoning, the following predictions were tested in Experiment 1: (1) spider images are remembered better than other images. (2) Spider images are accurately remembered, even when they have not been cued. (3) Presence of an uncued spider image leads to lower memory accuracy for the cued non-spider items. (4) The most critical hypothesis was that these effects would be enhanced in the SF group, as opposed to general effects that both groups show to an identical degree.

1.1. Methods

1.1.1. Participants

23 SFs and 24 NACs without any animal-oriented fears participated in the experiment. A preselection of participants took place in classes at several departments of the Dresden University of Technology, using the German “Spider Anxiety Screening” (SAS; Rinck et al., 2002). Students with scores lower than 5 or higher than 14 on the first three items (max. 18) were invited for further interviews and testing. These potential participants then completed the German version of the “Fear of Spiders Questionnaire” (FSQ; Rinck et al., 2002; Szymanski & O’Donohue, 1995) as well as the German FDD-DSM-IV inventory (Kuehner, 1997), which is a translation of the “Questionnaire for Depression Diagnosis” (Zimmermann, Coryell, Wilson, & Corenthal, 1986). Moreover, trained interviewers assessed the fulfillment of the DSM-IV criteria for specific phobia concerning spiders, using the International Diagnosis Checklist for DSM-IV (ICDL; Hiller, Zaudig, & Mombour, 1997) complemented by the eight-stage assessment scales of the Diagnostic Interview for Psychiatric Disorders—Research Version (F-DIPS; Margraf, Schneider, Soeder, Neumer, & Becker, 1996), which is the German version of the Anxiety Disorders Interview Scale (ADIS; DiNardo, Brown, & Barlow, 1994).

To qualify for the SF group, candidates had to reach a minimum F-DIPS “fear” score of 4 and a minimum “avoidance” score of 3, as well as a minimum score of 30 in the FSQ. 11 of the 23 SFs fulfilled all DSM-IV criteria for a specific phobia of spiders. The remaining ones met all criteria except criterion E, which requires significant impairment in everyday life. Considering the relative ease of avoiding threatening spiders in Northern Europe, not reaching this criterion is comprehensible and does not affect the questions of interest. The NAC participants were matched to the SF group with regard to age and gender. All candidates had a high school degree and were students of Dresden University of Technology. On average, the 21 female and 3 male members of the NAC group were

21.5 years old (S.D. = 2.0), the 20 female and 3 male SF participants had a mean age of 21.0 years (S.D. = 1.4). All of the final 46 volunteers were without history of any psychiatric disorder and had normal or corrected-to-normal vision. All of them gave their consent after being informed of their rights as participants in experimental studies. They received course credit or a payment equivalent to \$5 per hour in return for their participation.

1.1.2. Materials and apparatus

The experiment was controlled by MATLAB software using the Psychophysics Toolbox extensions (Brainard, 1997; Pelli, 1997), and presented on a gray background on 17-in. monitors with a 1024 × 768 resolution. The computer screen was placed approximately 70 cm away from the participant. Stimuli were 36 color images (side length 115 pixels) chosen by a team of experienced experts. Valence and arousal ratings of all these images were assessed with the participants of Experiment 2. They judged the valence of each image on a scale reaching from unpleasant (1) to pleasant (9), and the arousal of each image ranging from low (1) to high (9). Only the spider image was rated as at least mildly arousing. This was true for both of the groups, and significantly more so for the SFs (SF: $M = 8.2$, S.D. = .9; NAC: $M = 5.5$, S.D. = .8; $t(35) = 10.05$, $P < .001$). The valence of the spider image was rated as neutral by NACs ($M = 5.0$, S.D. = 1.5), and as negative by SFs ($M = 1.9$, S.D. = 1.7), yielding a significant group difference, $t(35) = 5.91$, $P < .001$. The remaining 35 noncritical images were all judged as neutral (e.g., backpack and carton) or positive (e.g., blossom and puppy) and not arousing.

1.1.3. Procedure

After completion of the State form of the German State-Trait Anxiety Inventory (STAI-S; Laux, Glanzmann, Schaffner, & Spielberger, 1981), volunteers were given written instructions regarding the experimental task. They were asked to attend to each cue string to prepare for a memory test and then make a decision to

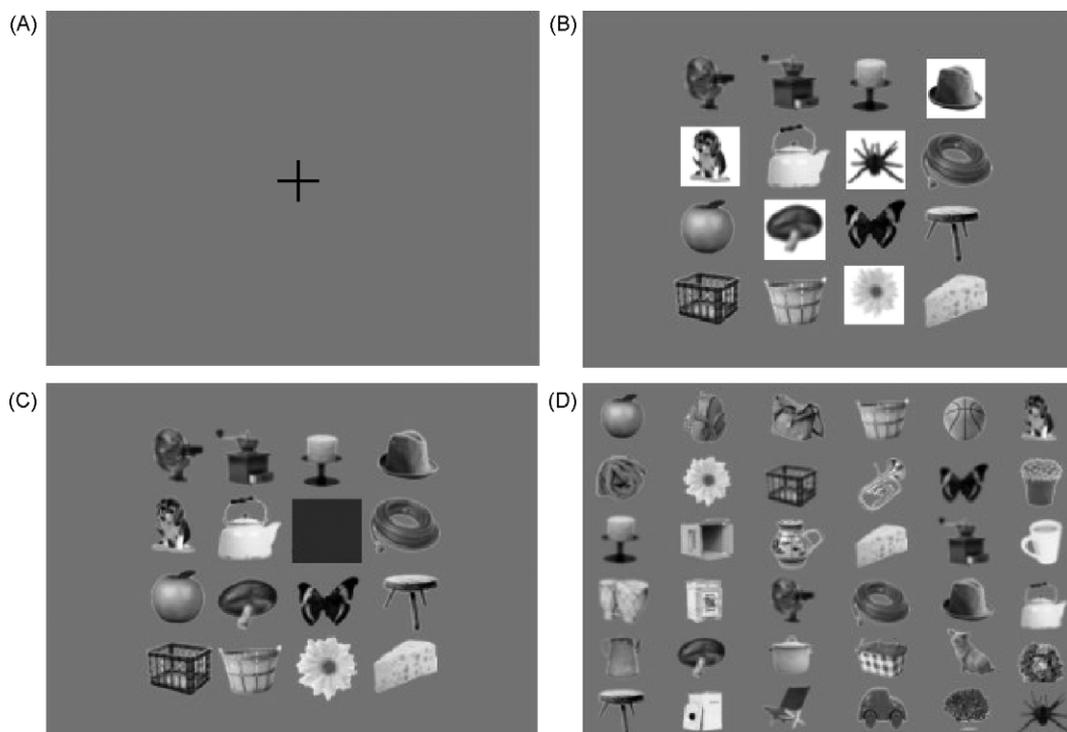


Fig. 1. Sample trial for Experiment 1 with a spider image cued and probed. Subsequent to a fixation cross (A) and the appearance of the 4×4 stimulus matrix, five items are cued one after another (for simplicity, shown simultaneously here) by the appearance of a white background (B). Immediately afterward, one item is hidden under a gray mask (C). Participants' task is to specify the identity of the hidden target item in the response menu (D). Note: actual stimuli were in color.

indicate the target item on a response menu. They studied a picture of the response menu including the 36 possible images for several minutes to get used to the object positions. An example trial is given in Fig. 1. Each trial started with a black fixation cross-presented for 500 ms (see Fig. 1A). Afterward, 16 images randomly chosen out of the pool of 36 images were randomly placed at the 16 positions of an invisible 4 × 4 grid. Within these matrices, center to center distances of the images were 120 pixels. A sample matrix with a spider is shown in Fig. 1B. After an initial orientation time of 150 ms, 5 images were cued one after another with an stimulus onset asynchrony (SOA) of 150 ms (see Fig. 1B). Shortly changing the background of the object from gray to white served as the cue. Immediately after the cue sequence, a single item was masked and probed for response by a dark gray square for 150 ms (see Fig. 1C). Immediately afterward, the stimuli matrix was replaced by a gray blank screen for 1000 ms. Then the response menu including all 36 possible objects was displayed (see Fig. 1D). Participants' task was to report the identity of the probed object by mouse-clicking on the correct image. After the response, but not later than 3000 ms, the response menu vanished. This temporal limitation for giving a response was included to encourage participants to give a speeded instead of an elaborated response. Written feedback was provided on screen after each trial. Breaks were possible whenever needed. After the experiment, participants completed another STAI-S as well as the Trait form of the German State-Trait Anxiety Inventory (STAI-T; Laux et al., 1981). Subsequently, all participants were debriefed regarding the study aims. SFs were also informed about treatment possibilities for spider phobia. A complete session lasted for about 70 min.

1.1.4. Design

The task is based on a 2 × 7 × 6 factorial design with the between-subjects factor “participant group” (SFs vs. NACs) and the within-subjects factors “spider position” (cue 1, cue 2, cue 3, cue 4, cue 5, uncued and none) and “test position” (cue 1, cue 2, cue 3, cue 4, cue 5 and uncued). “Spider position” describes the location of the spider image: it could be one of the 5 cued images (with “cue 1” being the first cued image and “cue 5” the last one), it could be one of the remaining 11 uncued items in the display (“uncued”), and there were trials without any spider among the 16 images (described by the condition “none”). Similarly, “test position” refers to the probed target item, which could be one of the 5 cued images or one of the 11 uncued images of the matrix. For each trial, spider position and test position were randomly chosen by the MATLAB experimental program. Each of the 42 possible combinations of spider position and test position was presented 10 times to

Table 1

Questionnaire scores (means, standard deviations and *t*-tests) of participants in Experiment 1.

	Spider fearfuls	Non-anxious controls	Significance of <i>t</i> -test (<i>df</i> = 45)
SAS	17.4 (3.5)	1.3 (1.7)	.001
FSQ	61.1 (17.7)	2.1 (2.9)	.001
FDD	9.0 (5.2)	7.8 (4.5)	n.s.
STAI-T	40.4 (6.9)	42.0 (7.5)	n.s.
STAI-S pre-exp.	36.4 (6.3)	37.0 (4.6)	n.s.
STAI-S post-exp.	37.9 (6.5)	38.1 (6.0)	n.s.

each participant, yielding a total of 420 experimental trials, preceded by six practice trials. For each data point, the participants' mean accuracy (percent correct) in identifying the probed item served as the dependent variable. In the analyses of this variable, interactions involving the factor “group” were of main interest, because they would suggest disorder-specific effects. In contrast, main effects of spider position and test position would suggest more general effects of threat on attention.

1.2. Results

1.2.1. Questionnaires

The mean questionnaire scores, standard deviations, and *t*-tests for the two participant groups are shown in Table 1. As expected, the two groups differed only with respect to fear of spiders (see SAS and FSQ scores). Moreover, the remaining average questionnaire scores fell within the normal range, giving no indication of depression, heightened trait anxiety, or heightened state anxiety.

1.2.2. Experimental task

Prior to the statistical data analyses, practice trials were discarded from the data set. Mean accuracy values in reporting the probed target object are shown in Table 2 for each experimental combination of spider position and test position in both groups. According to our specific hypotheses stated above, we computed several specific analyses of the relevant experimental conditions. Effect sizes are reported as η^2 for analyses of variance (ANOVAs) and as Cohen's *d* for *t*-tests. For ease of traceability of the specific analyses, the cells of Table 2 are labeled with letter combinations (lines a–n, columns A–F).

Hypotheses 1 and 4. Spider images are remembered better than other images. This effect should be enhanced in SFs.

Table 2 Mean memory accuracy (percent correct) and standard deviations (in parentheses) for each experimental combination of participant group, spider position, and test position in Experiment 1. Combinations in which the spider image was probed are highlighted by boldface.

Group and spider position	Test position					
	Cue 1 [A]	Cue 2 [B]	Cue 3 [C]	Cue 4 [D]	Cue 5 [E]	Uncued [F]
Spider fearfuls						
Cue 1 [a]	.84 (.16)	.41 (.24)	.49 (.26)	.65 (.26)	.77 (.18)	.37 (.34)
Cue 2 [b]	.52 (.25)	.83 (.24)	.50 (.26)	.70 (.15)	.78 (.16)	.37 (.34)
Cue 3 [c]	.50 (.29)	.39 (.28)	.80 (.24)	.61 (.21)	.81 (.15)	.38 (.35)
Cue 4 [d]	.47 (.28)	.43 (.25)	.51 (.24)	.89 (.15)	.75 (.15)	.42 (.37)
Cue 5 [e]	.46 (.26)	.46 (.26)	.50 (.24)	.66 (.16)	.97 (.06)	.37 (.34)
Uncued [f]	.51 (.24)	.43 (.29)	.46 (.26)	.62 (.23)	.78 (.17)	.62 (.33)
None [g]	.50 (.25)	.42 (.23)	.49 (.28)	.73 (.20)	.82 (.17)	.37 (.32)
Non-anxious controls						
Cue 1 [a]	.58 (.22)	.31 (.22)	.37 (.19)	.66 (.16)	.71 (.18)	.18 (.19)
Cue 2 [b]	.45 (.24)	.46 (.22)	.34 (.19)	.61 (.23)	.74 (.17)	.18 (.20)
Cue 3 [c]	.49 (.24)	.27 (.16)	.60 (.22)	.64 (.21)	.77 (.17)	.18 (.17)
Cue 4 [d]	.43 (.24)	.29 (.17)	.38 (.14)	.73 (.17)	.73 (.15)	.15 (.16)
Cue 5 [e]	.47 (.25)	.19 (.12)	.40 (.19)	.76 (.17)	.84 (.13)	.18 (.21)
Uncued [f]	.40 (.26)	.26 (.15)	.38 (.21)	.62 (.19)	.76 (.14)	.24 (.22)
None [g]	.49 (.29)	.27 (.16)	.34 (.18)	.56 (.17)	.66 (.17)	.21 (.22)

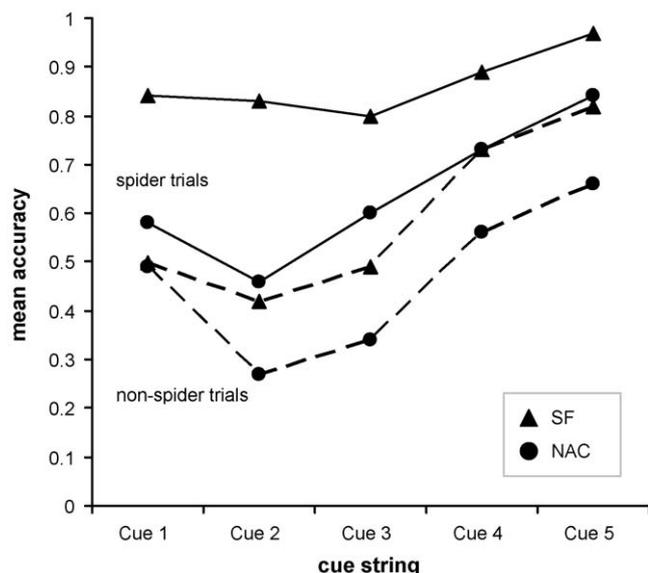


Fig. 2. Serial position effects in Experiment 1: mean memory accuracy for spider targets versus non-spider targets, depending on group and position within the cue string.

To test whether the spider item received a favored role in VWM, and whether that was the case in both groups or only in SFs, we compared the two groups' accuracy rates for spider-free trials (no spider within the display) to those for spider-target trials (a spider image was cued and tested), at each test position.¹ For the accuracy scores of the relevant data points, we computed a $2 \times 2 \times 5$ ANOVA including the between-subjects factor *group* (SFs vs. NACs) and the within-subjects factors *spider presence* (spider-target trials vs. non-spider trials) and *test position* (cue 1, cue 2, cue 3, cue 4, and cue 5). The results are shown in Fig. 2.

All main effects reached significance, indicating that on average, SFs' memory accuracy was higher than that of NACs, *group*: $F(1,45) = 27.0, P < .001, \eta^2 = .38$. Additional two-way *group* \times *test position* ANOVAs, separated for the neutral versus spider condition, confirmed that this was true for both neutral, *group*: $F(1,45) = 10.1, P = .003, \eta^2 = .18$, and spider trials, *group*: $F(1,45) = 29.1, P < .001, \eta^2 = .39$. Regarding the three-way ANOVA, images perceived just prior to the memory test were remembered better than items shown earlier in the cue string, *test position*: $F(4,180) = 53.4, P < .001, \eta^2 = .54$. Beyond that, participants generally revealed better memory for spiders than for non-spider images, *spider presence*: $F(1,45) = 97.4, P < .001, \eta^2 = .68$. This enhancement effect for spiders tended to be stronger in SFs, *spider presence* \times *group*: $F(1,45) = 3.8, P = .057$. However, additional two-way *spider presence* \times *test position* ANOVAs, separated for the two groups, confirmed that spiders were remembered better than non-spiders, both by SFs, *spider presence*: $F(1,22) = 62.0, P < .001, \eta^2 = .74$, and by NACs, *spider presence*: $F(1,23) = 35.6, P < .001, \eta^2 = .61$.

Moreover, serial position effects were weakened in spider strings compared to non-spider strings, *spider presence* \times *test position*: $F(4,180) = 4.4, P = .002, \eta^2 = .09$, indicating that in both groups, the accurate memorization of a spider image was less dependent on its position within the cue string compared to neutral image strings. This flattening of the spider serial position curve was particularly obvious in SFs, *group* \times *spider presence* \times *test position*: $F(4,180) = 4.6, P = .001, \eta^2 = .09$. This interpretation of statistical results was confirmed by additional *group* \times *test position* ANOVAs, separated for neutral versus spider strings. In the two groups, the serial position effects were comparably large for non-spider trials, *group* \times *test position*: $F(4,180) = 1.6, P = .189, \eta^2 = .03$, but SFs exhibited significantly smaller serial position effects than NACs for spiders, *group* \times *test position*: $F(4,180) = 5.5, P < .001, \eta^2 = .11$. Additional two-way *spider presence* \times *test position* ANOVAs, separated for the two groups, led to a similar conclusion: while serial position effects were significantly reduced for spider trials in the SFs group, *test position* \times *spider presence*: $F(4,88) = 7.9, P < .001, \eta^2 = .27$, there was no such enhancement effect in the NACs group, *test position* \times *spider presence*: $F(4,92) = 1.7, P = .160, \eta^2 = .07$. However, even SFs did not memorize spiders completely independently of their position within VWM. Additional one-way ANOVAs of the factor *test position*, separately for each group \times *spider presence* combination (i.e., each of the four graphs depicted in Fig. 2), all indicated significant serial position effects, even for spiders remembered by SFs, $F(4,88) = 6.1, P < .001, \eta^2 = .22$, all others: all $F(4,88/92) > 19.0$, all $P < .001$, all $\eta^2 > .45$. In sum, we found that spider images were indeed remembered better than other images, particularly by SFs, and that the serial position effects were indeed smallest for spiders remembered by SFs. They did not disappear altogether, though.

Table 3

Specific memory accuracy comparisons for Experiment 1. (A) Mean memory accuracy for uncued non-spider items versus uncued spider items. (B) Mean memory accuracy for cued non-spider items versus uncued spider items. (C) Mean memory accuracy to cued versus uncued spider items. (D) Mean memory accuracy for cued non-threatening items, depending on the presence of a spider item among the uncued items.

Experimental conditions	Group	
	SFs	NACs
(A)		
Uncued non-spider items	.37 (.32)	.21 (.22)
Uncued spider items	.62 (.33)	.24 (.22)
(B)		
Cued non-spider items	.59 (.16)	.46 (.12)
Uncued spider items	.62 (.33)	.24 (.22)
(C)		
Cued spider items	.86 (.15)	.65 (.13)
Uncued spider items	.62 (.33)	.24 (.22)
(D)		
No presence of an uncued spider item	.59 (.16)	.46 (.12)
Presence of an uncued spider item	.56 (.19)	.48 (.10)

test position: $F(4,180) = 4.6, P = .001, \eta^2 = .09$. This interpretation of statistical results was confirmed by additional *group* \times *test position* ANOVAs, separated for neutral versus spider strings. In the two groups, the serial position effects were comparably large for non-spider trials, *group* \times *test position*: $F(4,180) = 1.6, P = .189, \eta^2 = .03$, but SFs exhibited significantly smaller serial position effects than NACs for spiders, *group* \times *test position*: $F(4,180) = 5.5, P < .001, \eta^2 = .11$. Additional two-way *spider presence* \times *test position* ANOVAs, separated for the two groups, led to a similar conclusion: while serial position effects were significantly reduced for spider trials in the SFs group, *test position* \times *spider presence*: $F(4,88) = 7.9, P < .001, \eta^2 = .27$, there was no such enhancement effect in the NACs group, *test position* \times *spider presence*: $F(4,92) = 1.7, P = .160, \eta^2 = .07$. However, even SFs did not memorize spiders completely independently of their position within VWM. Additional one-way ANOVAs of the factor *test position*, separately for each group \times *spider presence* combination (i.e., each of the four graphs depicted in Fig. 2), all indicated significant serial position effects, even for spiders remembered by SFs, $F(4,88) = 6.1, P < .001, \eta^2 = .22$, all others: all $F(4,88/92) > 19.0$, all $P < .001$, all $\eta^2 > .45$. In sum, we found that spider images were indeed remembered better than other images, particularly by SFs, and that the serial position effects were indeed smallest for spiders remembered by SFs. They did not disappear altogether, though.

Hypotheses 2–4. Spiders are accurately remembered by SFs, even when they have not been cued, and the presence of an uncued spider leads to lower memory for the cued non-spider items.

These hypotheses were tested in a set of related analyses.

(A) *Memory for uncued non-spiders versus uncued spiders.* We first analyzed memory accuracy for (a) uncued spider items versus (b) uncued non-spider items in non-spider trials in both groups.² These data (see Table 3A) were subjected to 2×2 ANOVA, containing the factors *group* and *test item* (spider and non-spider). The analysis revealed that spiders were recalled better than non-spiders, *test item*: $F(1,45) = 14.0, P = .001, \eta^2 = .24$, and that SFs showed better memory than NACs, *group*: $F(1,45) = 14.1, P < .001, \eta^2 = .24$. These effects were qualified by a significant interaction, $F(1,45) = 8.0, P = .007, \eta^2 = .15$, however, due to SFs remembering uncued spiders particularly well. To supplement this interpretation, additional *t*-tests were calculated. Regarding uncued non-spiders,

¹ The spider-target trials are given in the 10 cells for which test position equals spider position in Table 2, shown in boldface (aA, bB, cC, dD, and eE for each group), implying that a spider was cued and tested. The corresponding spider-free trials are those depicted in the line "spider position = none" (cells gA, gB, gC, gD, and gE for each group), implying that displays contained no spiders.

² For (a), both cells fF of Table 2 were relevant and for (b), cells gF were included.

there was a tendency of SFs showing better memory than NACs, $t(45) = 1.9, P = .062, d = .58$, while uncued spiders were significantly better recalled by SFs and NACs, $t(45) = 4.6, P < .001, d = 1.35$. In the NAC group, memory for uncued spiders versus non-spiders did not differ, $t(23) < 1, P = .430, d = .14$. In the SF group, however, there was a memory advantage for uncued spiders compared to uncued non-spiders, $t(22) = 3.9, P = .001, d = .77$.

(B) *Memory to cued non-spiders versus uncued spiders.* As mean memory accuracy for uncued spiders was very high in the SF group ($M = .62$), we tested whether the mere content of spider images was strong enough to outweigh the effect of cueing for non-threatening items (see Table 3B). Therefore, we compared mean accuracy for the uncued spiders to mean accuracy for cued items in non-spider trials.³ For the relevant subset of the data, a 2×2 ANOVA was computed, involving the between-subjects factor *group* and the within-subjects factor *probe* (cued non-spider item and uncued spider item). This analysis yielded a significant interaction of both factors, $F(1,45) = 10.3, P = .002, \eta^2 = .19$, and additional *t*-tests confirmed a cueing effect for NACs, who remembered cued non-spiders better than uncued spiders, $t(23) = 4.6, P < .001, d = 1.24$. For SFs, however, uncued spiders were remembered just as well as cued non-spiders, $t(22) = .4, P = .692, d = .12$. Thus, in SFs, the threat value of the spider did indeed outweigh the effect of cueing for other items.

(C) *Memory for cued spiders versus uncued spiders.* Analysis (B) suggests that for SFs, the threat value of the spider itself served as an exogenous cue that was as strong as the effects of the cueing procedure on non-spider images. Therefore, one might wonder whether the cueing procedure had any effect on spider images at all. To answer this question, we compared accuracy for the uncued spiders to accuracy for cued ones⁴ (see Table 3C), computing a 2×2 ANOVA with the factors *group* and *cueing status* (cued spider and uncued spider). Overall, cued spiders were remembered better than uncued ones, *cueing status*: $F(1,45) = 113.1, P < .001, \eta^2 = .72$. This cueing effect was stronger in NACs than in SFs (.41 vs. .24), *cueing status* \times *group*: $F(1,45) = 6.5, P = .014, \eta^2 = .13$, but significant for both NACs, $t(23) = 10.5, P < .001, d = 2.27$, and SFs, $t(22) = 5.2, P < .001, d = .94$. Thus, the cueing procedure had the intended effect on memory accuracy, even for spider images in SFs.

(D) *Distraction caused by uncued spiders.* The previous analyses revealed a memory enhancement for uncued spiders in SFs. This raises the question whether this enhancement comes at the expense of cued non-spider images, or whether SFs show this advantage for uncued spiders *in addition* to remembering the cued items. To answer this question, we analyzed accuracy for cued non-spider items, depending on whether a spider was present among the 11 uncued items or not.⁵ The relevant data (see Table 3D) were subjected to a 2×2 ANOVA with the factors *group* and *presence of uncued spider* (present and not present). This analysis revealed neither an effect of *spider presence*, $F(1,45) = .2, P = .666, \eta^2 = .01$, nor an interaction, $F(1,45) = 3.2, P = .078, \eta^2 = .07$, indicating that in both groups, accuracy for cued non-spiders was unaffected by the presence of an uncued spider. This conclusion was confirmed by *t*-tests, computed separately for each group (NACs: $t(23) < 1, d = .18$; SFs: $t(22) = 1.6, P = .119, d = .17$). Thus, we have to conclude that the improved memory of SFs for uncued spiders did not come at the expense of the cued items.

1.2.3. Exclusion of alternative explanations

Threat advantage is due to higher frequency of appearance and related response bias. In the experiment presented above, the critical spider item is indeed most often the core of a probe compared to all of the noncritical items. That is, it would be adaptive to respond with the spider response as often as possible. It might even be that participants somehow manage to process the critical images more efficiently during the session due to their frequent occurrence. As the task revealed significant group differences, we are not given reason to doubt the existence of disorder-specific VWM biases. However, it remains possible that the memory preference effects found for spiders in both groups trace back to such a frequency saliency instead of, for instance, evolutionary relevance. To test the hypothesis whether the spider response is used more frequently, we compared hits (uncued item correctly reported as spider) and false alarm rates (uncued item mistaken as a spider) in both groups on condition that (a) a cued spider had been presented within the display versus (b) no spider had been shown at all. A signal detection analysis could not be carried out as false alarm rates were at zero in most participants. A descriptive inspection of the parameters ruled out the alternative explanation of a response bias in favor of spiders in SFs, as they reached clearly higher hit rates than NACs, (a) 62% versus 24%, while showing the same low false alarm rates, (a) 1% versus 4% and (b) 1% versus 1%.

Threat advantage is due to psychophysical uniqueness of the spider image. The spider pictures used in this experiment are, compared to most other pictures, particularly salient due to their dark color, specific shape and their depiction as animals. To test whether threat advantage effects found in both groups were due to such psychophysical characteristics rather than the threat value of the spider, we compared the hit rates for the spider image to the hit rates for the butterfly image, which was similarly dark and characteristic in shape. The analysis indicated a significantly greater hit rate for spiders (hit rates spider: NAC: $M = .58$, SF: $M = .82$, hit rates butterfly: NAC: $M = .48$, SF: $M = .54$), disclaiming mere psychophysical salience as causal for the results observed in both groups for spiders.

1.3. Discussion

In our earlier study (Reinecke et al., 2006) we found that both SFs and NACs remembered cued spider images better than cued non-negative images. This memory advantage seemed to be independent of the spider item's serial position within VWM, as images of spiders were remembered almost equally well at all test positions. The current experiment was designed to find out whether these findings might have been artifacts of the long initial orientation time of 500 ms, by shortening it to a mere 150 ms.

Surprisingly, this manipulation did not decrease memory effects in the SF group. Instead, we observed changes in the effects exhibited by the NAC group. We still found memory advantages for cued spiders in both groups, however, this advantage tended to be stronger in SFs. While memory for cued spiders was still almost independent of test position in SFs, NACs now showed clear serial position effects for both spider and non-spider items. Also, we replicated the most important result reported by Reinecke et al. (2006): even with the short initial orientation time of 150 ms, SFs exhibited an impressive memory advantage for uncued spiders. To summarize, we have to conclude that NACs, rather than SFs, used strategic processes during the 500 ms interval of Reinecke et al. (2006). For them, the change to 150 ms yielded differences in memory accuracy, while performance of the SFs remained largely unaffected. The latter finding suggests that the effects observed in SFs are mainly based on

³ The mean accuracy in remembering uncued spider items is depicted in cell ff of Table 2, the relevant cells for calculating the mean accuracy in remembering cued items in non-spider trials are gA, gB, gC, gD, and gE for each group.

⁴ The mean accuracy in remembering uncued spider items is depicted in cell ff of Table 2, the relevant cells for calculating the mean accuracy in remembering cued spider items are aA, aB, aC, aD, and aE for each group.

⁵ For the condition *presence of uncued spider*, cells fA, fB, fC, fD, and fE of Table 2 were relevant for each group. For the condition *no spider presence*, we calculated with cells gA, gB, gC, gD, and gE for each group.

automatic processes rather than strategic processes or artifacts of the procedure.

2. Experiment 2: VWM for snakes in SFs

Experiment 1 revealed that the VWM advantage of spiders in SFs is not due to the 500 ms initial orientation time. It is still unclear, however, whether the advantage is threat-specific, or whether SFs would show a VWM advantage for any kind of negative materials. If the latter was true, it is most likely that the advantage would also occur with other evolutionary relevant animals such as snakes (Ohman et al., 2001). Experiment 2 was designed to answer this question. It was identical to Experiment 1, except that the spider image was replaced by an image of a snake. As in Experiment 1, the position of this image within the cue string was manipulated, and a group of SFs were compared to a group of NACs. In addition, participants of both groups lacked any fear of snakes. As in the previous experiment, the snake image is special in many ways compared to the remaining items, for instance in evolutionary relevance and color. However, we may assume that it is comparably special to both groups, as it is not related to a phobic disorder of the participants. Therefore, we may expect that general VWM advantages for the snake will occur in Experiment 2, while the group differences observed earlier will disappear. In particular, we tested the following hypotheses in Experiment 2: (1) snake images will be remembered better than non-negative images in both groups, but without attenuation of serial position effects. (2) Memory for uncued snake images outside the cue string should not be enhanced. (3) Therefore, the presence of a snake beyond the cued set should not lead to lower memory accuracy for the cued non-snake items. (4) In general, there should not be any differences between the two groups.

2.1. Methods

2.1.1. Participants

18 SFs and 19 NACs without any animal oriented fears who had not participated in Experiment 1 were tested. Prescreening, interviewing, and diagnosis were identical to the first experiment, except that the “Snake Anxiety Screening” questionnaire (SCANS; Reinecke, Hoyer, Rinck, & Becker, in press) was added to the questionnaires. Only individuals with scores lower than 5 or higher than 14 on the SAS, and scores lower than 5 on the SCANS participated in the experiment. On average, the 17 female and 2 male members of the NACs group were 21.1 years old (S.D. = 2.7), the 16 female and 2 male participants of the SFs group had a mean age of 20.7 years (S.D. = 1.8). All of the final 37 volunteers were without history of any psychiatric disorder and had normal or corrected-to-normal vision. All of them gave their consent after being informed of their rights as participants in experimental studies. They received course credit or a payment equivalent to \$5 per hour in return for their participation.

2.1.2. Materials, apparatus, design, and procedure

Materials, apparatus, design, and procedure were identical to those of Experiment 1, except that the spider image used in Experiment 1 was replaced by an image of a snake with the same high contrast. The experiment was based on the same $2 \times 7 \times 6$ factorial design as the first experiment, except that *spider* was replaced by *snake*. Where appropriate, the present data of the SF group were also analyzed together with the corresponding data of Experiment 1, in order to test whether the factors of interest would interact with the type of threat stimulus (Exp. 1: spider and Exp. 2: snake). This would indicate that the corresponding effects differ significantly between experiments, and therefore between spiders and snakes. Moreover, after Experiment 2, the participants rated all

Table 4

Questionnaire scores (means, standard deviations and *t*-tests) of participants in Experiment 2.

	Spider fearfuls	Non-anxious controls	Significance of <i>t</i> -test (<i>df</i> = 35)
SAS spider	19.1 (3.8)	.5 (.7)	.001
SCANS snake	2.4 (2.8)	1.3 (2.0)	n.s.
FSQ	69.1 (21.2)	1.8 (2.3)	.001
FDD	8.2 (4.1)	5.5 (4.0)	n.s.
STAI-T	39.7 (7.9)	35.5 (8.2)	n.s.
STAI-S pre-exp.	36.1 (6.7)	32.4 (5.8)	n.s.
STAI-S post-exp.	35.9 (5.6)	31.3 (7.7)	n.s.

images from Experiments 1 and 2, including the spider image and the snake image, regarding valence and arousal. For the snake image, there were no rating differences between the two groups. Both groups judged the snake image to be neutrally valenced (SF: $M = 4.9$, S.D. = 1.6; NAC: $M = 5.2$, S.D. = 2.1; $t(35) = .44$, $P = .665$) and mildly arousing (SF: $M = 6.1$, S.D. = .9; NAC: $M = 5.5$, S.D. = .9; $t(35) = 1.75$, $P = .089$).

2.2. Results

2.2.1. Questionnaires

The mean questionnaire scores, standard deviations, and *t*-tests for the two participant groups are shown in Table 4. As expected, SFs and NACs differed only with respect to fear of spiders (see SAS and FSQ scores), and neither of them showed fear of snakes (SCANS). Moreover, the remaining questionnaire scores fell within the normal range, giving no indication of depression, heightened trait anxiety, or heightened state anxiety.

2.2.2. Experimental task

Data aggregation and analysis were identical to the experiment described before. Table 5 shows mean accuracy in memorizing the probed target object, separately for each experimental combination of snake position, test position, and participant group.

Hypotheses 1 and 5. Snake images are remembered better than other images by both groups, without differences between the two groups and without reduction of serial position effects.

Similar to Experiment 1, we compared the two groups' accuracy rates for snake-free trials (no snake within the display) to those for snake-target trials (a snake image was cued and tested), at each test position.⁶ The relevant subset of the data was analyzed by a $2 \times 2 \times 5$ ANOVA, involving the between-subjects factor *group* (SFs vs. NACs) and the within-subjects factors *snake presence* (snake-target trials vs. no snake trials) and *test position* (cue 1, cue 2, cue 3, cue 4, and cue 5). Fig. 3 depicts the results. Our analysis revealed that both groups showed a similar memory advantage for snake items compared to non-snake items, as confirmed by a significant main effect of the factor *snake presence*, $F(1,35) = 37.1$, $P < .001$, $\eta^2 = .52$, a non-significant main effect of the factor *group*, $F(1,35) < 1$, and a non-significant interaction of both factors, $F(1,35) < 1$. Also, in both groups, recently cued items were generally recalled better than items cued earlier, *test position*: $F(4,140) = 55.9$, $P < .001$, $\eta^2 = .62$, *test position* \times *group*: $F(4,140) < 1$. This was true for snake strings and non-snake strings in both groups, as there was neither an interaction of the factors *snake presence* and *test position*, $F(4,140) = 1.3$, $P = .257$, $\eta^2 = .04$, nor a three-way interaction, $F(4,140) = 1.8$, $P = .126$, $\eta^2 = .05$. To summarize, snakes were indeed memorized better than non-snake

⁶ The snake-target trials are given in the 10 cells shown in boldface in Table 5 (aA, bB, cC, dD, and eE for each group). The corresponding snake-free trials are those depicted in cells gA, gB, gC, gD, and gE for each group.

Table 5
Mean memory accuracy (percent correct) and standard deviations (in parentheses) for each experimental combination of participant group, snake position, and test position in Experiment 2. Combinations in which the snake image was probed are highlighted by boldface.

Group and snake position	Test position					
	Cue 1 [A]	Cue 2 [B]	Cue 3 [C]	Cue 4 [D]	Cue 5 [E]	Uncued [F]
Spider fearfuls						
Cue 1 [a]	.50 (.24)	.29 (.18)	.38 (.15)	.62 (.16)	.73 (.16)	.16 (.10)
Cue 2 [b]	.39 (.23)	.53 (.26)	.42 (.21)	.64 (.17)	.78 (.15)	.14 (.10)
Cue 3 [c]	.45 (.20)	.32 (.14)	.52 (.19)	.63 (.18)	.77 (.17)	.15 (.13)
Cue 4 [d]	.49 (.21)	.30 (.16)	.31 (.10)	.78 (.14)	.79 (.10)	.10 (.19)
Cue 5 [e]	.39 (.16)	.28 (.20)	.42 (.19)	.61 (.21)	.83 (.15)	.11 (.09)
Uncued [f]	.40 (.21)	.29 (.16)	.39 (.20)	.63 (.20)	.69 (.24)	.21 (.21)
None [g]	.45 (.16)	.28 (.19)	.44 (.14)	.63 (.23)	.72 (.21)	.15 (.11)
Non-anxious controls						
Cue 1 [a]	.56 (.18)	.30 (.17)	.40 (.19)	.61 (.20)	.71 (.13)	.16 (.20)
Cue 2 [b]	.41 (.20)	.47 (.24)	.39 (.20)	.66 (.16)	.70 (.14)	.14 (.20)
Cue 3 [c]	.40 (.22)	.37 (.20)	.57 (.20)	.64 (.14)	.68 (.24)	.20 (.20)
Cue 4 [d]	.40 (.21)	.34 (.18)	.41 (.16)	.73 (.17)	.72 (.18)	.15 (.21)
Cue 5 [e]	.43 (.21)	.28 (.23)	.44 (.16)	.65 (.13)	.84 (.15)	.13 (.17)
Uncued [f]	.37 (.21)	.27 (.17)	.44 (.19)	.64 (.15)	.73 (.16)	.21 (.16)
None [g]	.41 (.24)	.32 (.14)	.37 (.12)	.62 (.15)	.69 (.19)	.17 (.21)

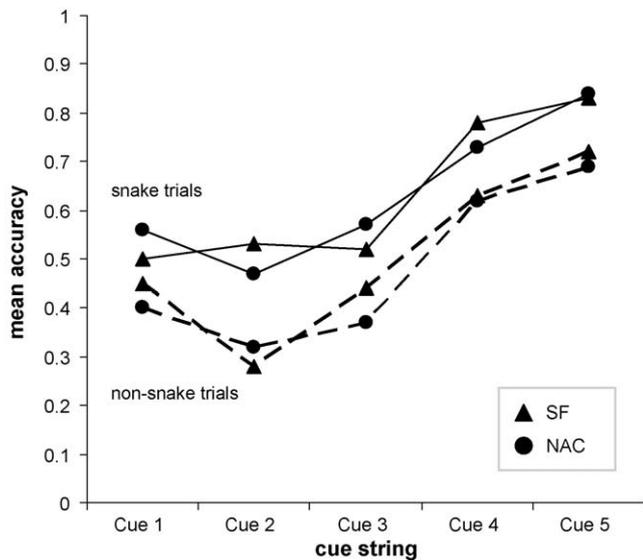


Fig. 3. Serial position effects in Experiment 2: mean memory accuracy for snake targets versus non-snake targets, depending on group and position within the cue string.

items, and this advantage was similar at all cue positions, such that serial position effects within the snake cue string were very similar to those observed for non-snake strings. These effects occurred similarly in both groups, and neither group showed better memory.

Table 6
Specific memory accuracy comparisons for Experiment 2. (A) Mean memory accuracy for uncued non-snake items versus uncued snake items. (B) Mean memory accuracy for cued non-threatening items, depending on the presence of a snake item among the non-cued items.

Experimental conditions	Group	
	SFs	NACs
(A)		
Uncued non-snake items	.15 (.11)	.17 (.21)
Uncued snake items	.21 (.21)	.21 (.16)
(B)		
No presence of an uncued snake item	.51 (.10)	.48 (.10)
Presence of an uncued snake item	.48 (.11)	.49 (.10)

To test whether the effects found here for snakes differ from those found for spiders in Experiment 1, an additional joint analysis was computed. In this analysis, only trials in which a threat item was cued and tested were included and subjected to a *group × item (spider and snake) × test position* three-way repeated measures ANOVA. The analysis confirmed that SFs showed better memory for spiders than snakes, *group × item*: $F(1,80) = 12.7$, $P < .001$, $\eta^2 = .14$. This was confirmed by additional *item × test position* ANOVAs, separated for the groups, SFs: *item*: $F(1,39) = 27.0$, $P < .001$, $\eta^2 = .41$, NACs: *item*: $F(1,41) < 1$. Moreover, SFs showed significantly smaller serial position effects for spiders than for snakes, while the position effects were comparable in the NAC group, *item × test position × group*: $F(4,320) = 2.4$, $P < .05$, $\eta^2 = .03$. Again, this was confirmed in additional *item × test position* ANOVAs, separately for each group, SFs: *item × test position*: $F(4,156) = 5.4$, $P < .001$, $\eta^2 = .12$, NACs: *item × test position*: $F(4,164) < 1$.

Hypotheses 2–4. No enhanced memory for uncued snake images in any of the groups. The presence of uncued snakes will not cause lower memory accuracy for the cued non-snake items.

These hypotheses were tested in a set of analyses corresponding to the ones of Experiment 1.

(A) *Memory for uncued snakes versus uncued non-snakes.* To test whether memory for snakes beyond the cued set is improved, and whether there are differences between SFs and NACs, mean memory accuracy for uncued snake items was compared to mean accuracy for non-snake items beyond the cued set.⁷ The same 2×2 ANOVA as in the first experiment including the factors *group* and *probe* (snake and non-snake) was performed, see Table 6A. The analysis revealed that neither a main effect nor the interaction was significant, all $F(1,35) < 2.2$, all $P > .14$, all $\eta^2 < .06$, suggesting that none of the groups showed a memory advantage for uncued snakes. To test whether the strong enhancement in the memorization of uncued spiders in Experiment 1 does indeed reflect disorder-specificity, we compared accuracy for uncued spiders (Exp. 1) to accuracy for uncued snakes (Exp. 2). A 2×2 ANOVA was calculated, involving the between-subjects factors *item* (spider and snake) and *group*. SFs showed better memory for uncued spiders than for uncued snakes, *item × group*:

⁷ The mean memory for uncued snake items is depicted in cell fF of Table 5 for each group. Cell gF of each group was included for uncued non-snake items.

Table 7
Comparison of results observed in three different experiments (Y = yes and N = no).

	Reinecke et al. (2006), 500 ms, spider	Experiment 1, 150 ms, spider	Experiment 2, 150 ms, snake
Memory advantage for cued critical item	Y (SF, NAC)	Y (SF, NAC)	Y (SF, NAC)
Extra advantage in SFs	N	Y	N
Weakening of position effects for critical item	Y (SF, NAC)	Y (SF)	N
Memory enhancement for uncued critical item	Y (SF)	Y (SF)	N
Distraction of cued items by uncued critical item	N	N	N

$F(1,80) = 11.8, P = .001, \eta^2 = .13$, SFs: $t(39) = 4.5, P < .001, d = 1.48$, NACs: $t(41) < 1, d = .16$.

(B) *Distraction caused by uncued snakes*. To test whether a snake item beyond the cue string interferes with memorization of the task-relevant items of the cued set, we compared mean accuracy for cued items in non-snake trials to mean accuracy for cued items in trials with an uncued snake.⁸ A 2×2 ANOVA with the factors *group* and *presence of uncued snake* (present and not present) was computed, see Table 6B. This analysis yielded no significant effect, all $F(1,35) < 1.7$, all $P > .20$, all $\eta^2 < .05$. Thus, in both groups, memory for cued items was unaffected by the presence of an uncued snake image. An additional *item* (snake and spider) \times *group* ANOVA combining results from the two experiments confirmed that the non-effect of an uncued snake item was similar to that of an uncued spider image in Experiment 1, *item* \times *group*: $F(1,80) = 2.2, P = .139, \eta^2 = .03$.

2.3. Discussion

In Experiment 2, cued snake images were remembered better than cued non-snake images. This was the only effect that replicated the results of the first experiment. Unlike Experiment 1, the memory advantage occurred to an identical degree in both groups, and it was approximately the same at all serial positions within VWM, such that serial position effects did not vanish in strings including snake images. In contrast to the cued snake images, uncued ones were not special at all. They were memorized as well as other uncued items, and they did not interfere with memorization of the cued items. Most importantly, all of these results were true for both groups to a similar degree. Unlike the spider image of Experiment 1, the snake image presented in Experiment 2 did not yield disorder-specific effects in SFs; and snakes were similarly special for SFs and NACs. This may reflect the evolutionary relevance that snakes have for all humans, independent of their fear of spiders.

3. General discussion

Cognitive theories of anxiety predict information processing biases in favor of threatening material, as long as processing takes place at an automatic versus strategic level (Mogg & Bradley, 1998; Williams et al., 1997). This assumption is confirmed by strong empirical evidence for an attentional bias for threat (Mathews & MacLeod, 2005), but only weak support for a memory bias in anxiety (Coles & Heimberg, 2002). Therefore, most of these models postulate that memory biases are not characteristic of anxiety. However, reviewing recent memory literature, most of the studies addressed a rather strategic long-term component of memory (Coles & Heimberg, 2002), whereas the link between attention and long-term memory, the highly automatic WM (Irwin & Zelinsky, 2002; Luck & Vogel, 1997; Wolfe, Reinecke, & Brawn, 2006),

⁸ For the condition *presence of uncued snake*, for each group, cells fA, fB, fC, fD, and fE of Table 5 were included. For the control condition, we calculated with cells gA, gB, gC, gD, and gE for each group.

remained largely neglected. This gap in bias research is regrettable, as the monitoring of threat – a function of WM – seems to be as relevant in managing one's anxiety as the detection of the phobic stimulus. The present study was designed to methodologically refine and extend earlier WM results of Reinecke et al. (2006). In Experiment 1, the long initial orientation time of 500 ms was replaced by a mere 150 ms to test whether this would strengthen group differences by leaving less room for uncontrolled strategic processing. In addition, Experiment 2 investigated whether any group differences were material-specific to spiders. Table 7 gives a comparative summary of the main results of the earlier experiment and the two experiments reported here.

In Experiment 1, we mostly replicated our earlier results (Reinecke et al., 2006). Cued spiders were memorized better than non-spider items in both groups. However, the reduction of the initial processing time prior to the cueing sequence led to a more precise distinction between SFs and NACs: (a) the memory advantage for cued spiders tended to be stronger in SFs than NACs, and (b) serial position effects for spider strings were significantly reduced only in SFs, not in NACs. This way, compared to our first application of the task, the initial time of only 150 ms reduced the memory advantages for spiders in NACs, not in SFs. Moreover, fearfuls were able to maintain their strong memory advantage for uncued spiders without any costs regarding cued items. This finding was observed by Reinecke et al. (2006) and in Experiment 1, suggesting that it is not based on strategic preprocessing of the spider image in SFs before the cue sequence starts. In Experiment 2, cued snake items were remembered better than non-snake items. This advantage occurred to an identical degree in both SFs and NACs. Furthermore, serial position effects in snake strings were very similar to those in non-snake strings, in both groups. Beyond this general advantage for cued snakes, memory for uncued snakes was not enhanced in any of the groups. This indicates that the group differences observed in our first study and in Experiment 1 are spider-specific: SFs only show memory advantages compared to NACs with spider materials, but not with snake materials. Compared to other pictures, snake images are special, but they are so to the same degree for SFs and NACs, and only spider images are truly threatening for SFs.

Summarizing, shortening the initial orientation time to 150 ms led to a stronger differentiation between anxious participants and control volunteers. This supports cognitive theories of anxiety in the assumption that processing biases occur if stimulus processing is automatic rather than strategic (Fox & Georgiou, 2004; Mathews & Mackintosh, 1998; Williams et al., 1997). However, the data also question the prediction of some of these models that anxiety is therefore not related to explicit memory biases (Mogg & Bradley, 1998; Williams et al., 1997). For instance, Williams et al. (1997) postulate that anxiety is characterized by increased vigilance for threat, resulting in attentional bias, but also by immediate avoidance of threat processing, resulting in the interruption of deeper elaboration in memory. Our data suggest that it might be worthwhile to extend the current classification of two components of information processing, attention versus memory, by an additional, intermediary module—the WM. In contrast to attention,

WM involves the monitoring of threat over and above its mere detection, and in contrast to long-term memory it works on a highly automatic processing level. In this article, we have investigated memory bias from this comparably new perspective, taking into account the stage of encoding at WM versus long-term memory level. In line with Fox and Georgiou (2004), our data suggest that we do find an explicit memory bias if threat is processed in an automatic manner. Phobic materials are favorably processed in VWM, while avoidance might come into play at a later processing stage. Therefore, we may conclude that “deeper elaboration” (Williams et al., 1997) starts beyond WM.

Another conclusion to be drawn from the present results is that the disorder-specific VWM effects described above are material-specific as well. Group differences were only observed with a spider as the critical image, not with snake images. Therefore, the group differences found in the spider conditions may indeed be attributed to the individual threat value of the spider image. This finding strengthens the assumption of Cave and Batty (2006) that specific anxiety representations are more highly activated in anxiety patients, and that the perception of threat items is therefore improved by the individuals' numerous experiences of searching for the feared objects.

Also, in both experiments reported here, participants showed better WM for spiders and snakes, even when these were not feared. This threat preference might reflect evolutionary relevance: quickly recognizing danger to be able to quickly reacting to it. This explanation would be highly compatible with earlier studies suggesting a general processing advantage for evolutionary relevant materials which signal danger (Cook & Mineka, 1991; Ohman et al., 2001; Seligman, 1971). Follow-up research will have to determine the exact factors contributing to this general processing advantage for spiders and snakes over neutral and positive objects. It may well be that salient visual features of the images (e.g., the shape or color of the animals) contribute to the effects. This alternative explanation is difficult to exclude because spiders and snakes necessarily look different from other animals and objects. Thus, the visual features of threatening images can never be fully equated with those of other objects. Nevertheless, it should be possible to control for the most salient features, such as the general shape or the color of the spiders and objects. However, it also could be argued that the threat advantages observed in both groups were due to the higher presentation rate of spider and snake images, resulting in either (a) a response bias that would mean participants answer with the threat image if in doubt, or (b) the threat stimulus becoming more salient or more easily to remember over time. While we were able to rule out a response bias in favor of the threat item, we cannot exclude the explanation that threat effects found in both groups are the mere results of increased re-appearance of the image. While this would indeed mean that threat effects that appeared in both groups have to be interpreted with reservation, it would nevertheless not question the differences between groups reported here, as both groups have been exposed to the same number of repetitions of the spider image in Experiment 1.

Another limitation of the current study is that data of Experiment 1 revealed that SFs already showed a memory advantage over NACs in purely neutral trials. At first sight, this baseline difference seems to cause interpretation problems, questioning how far we can trust memory differences between the groups in spider trials if they already differ in non-threat trials. However, our current analysis is considering this problem in that our data interpretation focuses on the three-way interaction of the factors *group*, *test position* and *spider presence*. This interaction reaches statistical significance, implying that although groups might differ even when memorizing neutral displays, the SF group still shows an *additional* advantage in spider trials (compared to

the group's already increased memory level in neutral trials, and compared to controls). This latter comparison thereby also takes each group's mean accuracy in neutral trials into account and compares this to spider trials accuracy. Also, Experiment 2, which was designed and expected to show several no-between-group differences in contrast to Experiment 1, bases on smaller sample sizes than Experiment 1 (Exp. 1: $N = 47$ vs. Exp. 2: $N = 37$). One might argue that Experiment 2 might have been underpowered and therefore did not reveal the same group differences as found in Experiment 1. However, re-running all Experiment 1 analyses for randomly selected samples of 18 SFs and 19 NACs shows exactly the same group differences as found with the larger samples. Therefore, we can assume that the missing group differences in Experiment 2 are not merely due to inadequate experimental power.

Acknowledgements

Preparation of this article was supported by a grant from the German Research Foundation (DFG) to Eni S. Becker and Mike Rinck. We are grateful to Heidi Knuepfer for her essential support in programming the experimental script and to Kira Marschner and Kristin Grundl who helped recruiting and testing the participants.

References

- Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: a proposed system and its control processes. In: Spence, K. W., & Spence, J. T. (Eds.), *The psychology of learning and motivation* (Vol. 2). New York, NY: Academic Press.
- Baddeley, A. D. (1992). Is working memory working? The fifteenth Bartlett lecture. *Quarterly Journal of Educational Psychology*, 44A, 1–31.
- Beck, A. T., Emery, G., & Greenberg, R. L. (1985). *Anxiety disorders and phobias*. New York, NY: Basic Books.
- Becker, E. S., & Rinck, M. (2004). Sensitivity and response bias in fear of spiders. *Cognition & Emotion*, 7, 961–976.
- Becker, E. S., Rinck, M., & Margraf, J. (1999). Memory bias on panic disorder. *Journal of Abnormal Psychology*, 103, 396–399.
- Brainard, D. H. (1997). The psychophysics toolbox. *Spatial Vision*, 10, 443–446.
- Carlsson, K., Pettersson, K. M., Lundquist, D., Karlsson, A., Ingvar, M., & Ohman, A. (2004). Fear and the amygdala: manipulation of awareness generates differential cerebral responses to phobic and fear-relevant (but nonfeared) stimuli. *Emotion*, 4, 340–353.
- Cave, K. R., & Batty, M. J. (2006). From searching for features to searching for threat: drawing the boundary between preattentive and attentive vision. *Visual Cognition*, 14, 629–647.
- Clark, D. M., & Wells, A. (1995). A cognitive model of social phobia. In: R. G. Heimberg, M. R. Liebowitz, D. A. Hope, & F. R. Schneider (Eds.), *Social phobia: diagnosis, assessment, treatment* (pp. 69–93). New York, NY: The Guilford Press.
- Coles, M. E., & Heimberg, R. G. (2002). Memory biases in the anxiety disorders: current status. *Clinical Psychology Review*, 22, 587–627.
- Cook, M., & Mineka, S. (1991). Selective associations in the origins of phobic fears and their implications for behavior therapy. In: P. Martin (Ed.), *Handbook of behavior therapy and psychological science: an integrative approach* (pp. 413–434). Oxford, UK: Pergamon Press.
- DiNardo, P. A., Brown, T. A., & Barlow, D. H. (1994). *Anxiety disorders interview schedule for DSM-IV: lifetime version (ADIS-IV-L)*. Albany, NY: Graywind Publications.
- Eysenck, M. W. (1992). *Anxiety: the cognitive perspective*. Hove, UK: Erlbaum.
- Fox, E., & Georgiou, G. A. (2004). The nature of attentional bias in human anxiety. In: R. W. Engle, G. Sedex, U. von Hecker, & D. N. Macintosh (Eds.), *Cognitive limitations in aging and psychopathology*. Cambridge: Cambridge University Press.
- Hiller, W., Zaudig, M., & Mombour, W. (1997). *IDCL—Internationale Diagnosen Checklisten fuer DSM-IV und ICD-10 (Manual, 31 Checklisten nach DSM-IV und Screening-Blatt)*. Goettingen, Germany: Hogrefe.
- Irwin, D. E., & Zelinsky, G. J. (2002). Eye movements and scene perception: memory for things observed. *Perception & Psychophysics*, 64, 882–895.
- Jonides, J. (1981). Voluntary versus automatic control over the mind's eye's movement. In: J. B. Long & A. D. Baddeley (Eds.), *Attention and performance IX*. Hillsdale, NJ: Erlbaum.
- Kindt, M., & Brosschot, J. F. (1997). Phobia-related bias for pictorial and linguistic stimuli. *Journal of Abnormal Psychology*, 106, 644–648.
- Kindt, M., & Brosschot, J. F. (1998). Cognitive avoidance in phobia. *Journal of Psychopathology and Behavioral Assessment*, 20, 43–55.
- Kuehner, C. (1997). *Fragebogen zur Depressionsdiagnostik nach DSM-IV (FDD-DSM-IV)*. Goettingen, Germany: Hogrefe.
- Kulas, J. F., Conger, J. C., & Smolin, J. M. (2003). The effects of emotion on memory: an investigation of attentional bias. *Journal of Anxiety Disorders*, 17, 103–113.
- Laux, L., Glanzmann, P., Schaffner, P., & Spielberger, C. D. (1981). *STAI: Das State-Trait-Angstinventar*. Weinheim, Germany: Beltz.

- Luck, S. J., & Vogel, E. K. (1997). The capacity of visual working memory for features and conjunctions. *Nature*, *390*, 279–281.
- Lundh, L.-G., Thulin, U., Czyzykow, S., & Oest, L.-G. (1998). Recognition bias for safe faces in panic disorder with agoraphobia. *Behaviour Research and Therapy*, *36*, 323–337.
- Margraf, J., Schneider, S., Soeder, U., Neumer, S., & Becker, E. S. (1996). Diagnostisches Interview bei psychischen Stoerungen (F-DIPS), unpublished manual.
- Mathews, A., & Mackintosh, B. (1998). A cognitive model of selective processing in anxiety. *Cognitive Therapy and Research*, *22*, 539–560.
- Mathews, A., & MacLeod, C. (2005). Cognitive vulnerability to emotional disorders. *Annual Review of Clinical Psychology*, *1*, 167–195.
- Mogg, K., & Bradley, B. P. (1998). A cognitive–motivational view analysis of anxiety. *Behaviour Research and Therapy*, *36*, 809–848.
- Mogg, K., & Bradley, B. P. (2006). Time course of attentional bias for fear-relevant pictures in spider-fearful individuals. *Behaviour Research and Therapy*, *44*, 1241–1250.
- Mueller, H. J., & Rabbitt, P. M. (1989). Reflexive and voluntary orienting of attention: time course of activation and resistance to interruption. *Journal of Experimental Psychology: Human Perception and Performance*, *15*, 315–330.
- Ohman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: detecting the snake in the grass. *Journal of Experimental Psychology: General*, *130*, 466–478.
- Ohman, A., & Mineka, S. (2001). Fears, phobias, and preparedness: toward an evolved module of fear and learning. *Psychological Review*, *108*, 483–522.
- Pelli, D. G. (1997). The Video Toolbox software for visual psychophysics: transforming numbers into movies. *Spatial Vision*, *10*, 437–442.
- Posner, M. I., & Snyder, C. R. R. (1975). Facilitation and inhibition in the processing of signals. In: Rabbitt, P. M., & Dornic, S. (Eds.), *Attention and performance* (Vol. 5). San Diego, CA: Academic Press.
- Reinecke, A., Hoyer, J., Rinck, M., & Becker, E. S. (in press). Zwei Kurzscreenings zur Messung von Angst vor Schlangen: Reliabilitaet und Validitaet im Vergleich zum SNAQ [Two short-screenings measuring fear of snakes: reliability and validity compared to the SNAQ]. *Klinische Diagnostik und Evaluation*.
- Reinecke, A., Rinck, M., & Becker, E. S. (2006). Spiders crawl easily through the bottleneck: visual working memory for negative stimuli. *Emotion*, *6*(3), 438–449.
- Reinecke, A., Rinck, M., & Becker, E. S. (2008). How preferential is the preferential encoding of threatening stimuli? Working memory biases in specific anxiety and the attentional blink. *Journal of Anxiety Disorders*, *22*, 655–670.
- Rinck, M., & Becker, E. S. (2005). A comparison of attentional biases and memory biases in women with social phobia and major depression. *Journal of Abnormal Psychology*, *114*, 62–74.
- Rinck, M., & Becker, E. S. (2006). Spider fearfults attend to threat, then quickly avoid it: evidence from eye movements. *Journal of Abnormal Psychology*, *115*, 213–238.
- Rinck, M., Bundschuh, S., Engler, S., Mueller, A., Wissmann, J., Ellwart, T., et al. (2002). Reliability and validity of German versions of three instruments measuring fear of spiders. *Diagnostica*, *48*, 141–149.
- Rinck, M., Reinecke, A., Ellwart, T., Heuer, K., & Becker, E. S. (2005). Speeded detection and increased distraction in fear of spiders: evidence from eye movements. *Journal of Abnormal Psychology*, *114*, 235–248.
- Rusted, J. L., & Dighton, K. (1991). Selective processing of threat-related material by spider phobias in a prose recall task. *Cognition & Emotion*, *5*, 123–132.
- Seligman, M. E. P. (1971). Phobias and preparedness. *Behavior Therapy*, *2*, 307–320.
- Szymanski, J., & O'Donohue, W. (1995). Fear of spiders questionnaire. *Journal of Behavior Therapy and Experimental Psychiatry*, *26*, 31–34.
- Thorpe, S. J., & Salkovskis, P. M. (1997). Information processing in spider phobics: the Stroop colour naming task may indicate strategic but not automatic attentional bias. *Behaviour Research and Therapy*, *35*, 131–144.
- Thorpe, S. J., & Salkovskis, P. M. (2000). Recall and recognition memory for spider information. *Journal of Anxiety Disorders*, *14*, 359–375.
- Watts, F. N. (1986). Cognitive processing in phobias. *Behavioural Psychotherapy*, *14*, 295–301.
- Watts, F. N., & Dalgleish, T. (1991). Memory for phobia-related words in spider phobics. *Cognition & Emotion*, *5*, 313–329.
- Wessel, I., & Merckelbach, H. (1997). The impact of anxiety on memory for details in spider phobics. *Applied Cognitive Psychology*, *11*, 223–231.
- Wessel, I., & Merckelbach, H. (1998). Memory for threat-relevant and threat-irrelevant cues in spider-phobics. *Cognition & Emotion*, *12*, 93–104.
- Williams, J. M. G., Watts, F. N., MacLeod, C., & Mathews, A. (1997). *Cognitive psychology and emotional disorders*. Chichester: John Wiley.
- Wolfe, J. M., Reinecke, A., & Brawn, P. (2006). Why don't we see changes? The role of attentional bottlenecks and limited visual memory. *Visual Cognition*, *14*, 749–780.
- Yonelinas, A. P., & Jacoby, L. L. (1995). Dissociating automatic and controlled processes in a memory search task: beyond implicit memory. *Psychological Research*, *57*, 156–165.
- Zimmermann, M., Coryell, W., Wilson, S., & Corenthal, C. (1986). A self-report scale to diagnose major depressive disorder. *Archives of General Psychiatry*, *43*, 1076–1081.