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# How preferential is the preferential encoding of threatening stimuli? Working memory biases in specific anxiety and the Attentional Blink

Andrea Reinecke [a,*], Mike Rinck [b], Eni S. Becker [b]

[a] Dresden University of Technology, Germany
[b] Radboud University Nijmegen, The Netherlands

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**Abstract**

Temporal visual working memory (VWM) biases in spider anxiety were studied with an Attentional Blink paradigm. In Experiment 1, participants viewed pictures sequentially presented at rates of 80 ms and were instructed to memorize two target pictures. We varied time between targets and valence of the second target (neutral: mushroom, positive: blossom, negative: spider). In Experiment 2, spider fearfuls and non-anxious controls (both without snake anxiety) participated. Here we tested two negative targets: disorder-related spiders and disorder-irrelevant snakes. Both positive and negative items were memorized more successfully than neutral targets. Spiders were preferentially recalled by spider fearfuls compared to non-anxious controls, implying temporal VWM biases in spider anxiety. This advantage for threat was not related to a disruption of the encoding of non-threatening targets presented before the threat item.


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Specific phobias belong to the most common mental disorders (e.g., ESEMed Investigators, 2004) with a lifetime prevalence of 8–12% (Kessler, Chiu, Demler, & Walters, 2005; Magee, Eaton, Wittchen, McGonagle, & Kessler, 1996) to 25.6% (Regier, Rae, Narrow, Kaelber, & Schatzberg, 1998). Impairments in everyday life caused by these disorders can be far reaching (Wittchen, Nelson, & Lachner, 1998). Cognitive models of anxiety (e.g., Beck, Emery, & Greenberg, 1985; Clark & Wells, 1995; Williams, Watts, MacLeod, & Mathews, 1997) postulate that disorder-specific biases in information processing are relevant for the etiology and maintenance of these disorders. Accordingly, a phobic seems to pay more attention to feared aspects of the environment (e.g., to spiders and spider webs). Phobics are more likely to notice feared stimuli, supporting their impression of a dangerous world, confirming their dysfunctional beliefs and resulting in increased checking behavior. In a spider phobic's world, it seems as if there are more spiders, enforcing their avoidance behaviors and thus the anxiety disorder is maintained.

Ample evidence exists in specific phobia that affected individuals show attentional biases for feared

* Corresponding author at: University of Oxford, Department of Psychiatry, Warneford Hospital, Oxford OX3 7JX, UK.
*E-mail address:* andrea.reinecke@psych.ox.co.uk (A. Reinecke).

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stimuli (for reviews, see Mathews & MacLeod, 2005; Williams et al., 1997), implying a fast and automatic shift of attention to threat items and therefore greater distractibility from other stimuli when threat is present. Empirical support for memory biases in specific phobia is less clear; some studies report memory biases, some do not (for a review, see Williams et al., 1997). One possible explanation for the strong evidence of attentional biases and weak evidence of memory biases, is found in the vigilance-avoidance theory (Williams et al., 1997). It implies a rapid switch of attention towards threatening stimuli, but avoidance of deeper elaboration on the feared materials. But exactly what is ''deeper elaboration''? Does it start in visual working memory (VWM)? This question is difficult to answer, as there seems to be a missing link in research on cognitive biases in specific phobia, namely the attentional bottleneck and VWM.

In an earlier study of visual working memory biases in anxiety disorders, we observed enhanced VWM for spider images in spider fearfuls compared to non-anxious controls in a spatial cueing paradigm (Reinecke, Rinck, & Becker, 2006). The results of this study imply that the avoidance of deeper elaboration on threatening materials (Williams et al., 1997) does not start in working memory. Moreover, the results suggest that the basis for disorder-specific VWM biases must be a preferential and very quick automatic encoding of spider items into VWM.

However, this previous study assessed only the *spatial aspects of working memory* biases, as the threatening image was presented among several non-threatening pictures. Specific details of this fast, automatic encoding process remain unexplained. Exactly how circumscribed is the preferential selection of threat items? Does it occur at the expense of other stimuli undergoing the capacity-limited encoding process? That is, would the presentation of a spider item interrupt the ongoing encoding of other items in the processing channel? Would it cause premature drop-out, resulting in incomplete processing of other items? To answer these questions, a paradigm with a high temporal, rather than spatial resolution was required. Such a task, addressing the consolidation of items, would allow for the investigation of *temporal working memory* biases in specific anxiety.

Fortunately such a task exists, namely the Attentional Blink (AB) paradigm. In an AB task, participants are asked to attend to a series of rapidly presented stimuli (i.e. letters, words, or pictures) and to focus on two targets (T1 and T2) defined by unique visual features (i.e. color, size, or category; Broadbent & Broadbent, 1987; Intraub, 1985; Kanwisher, 1987; Weichselgartner & Sperling, 1987), while the time between these two targets is varied. For instance, Shapiro, Raymond, and Arnell (1994) asked their participants to attend to a stream of black letters, identify the first target (indicated by a white color) and determine whether a second target (a black ''X''), was present. For a wide variety of emotionally neutral materials, observers showed reduced report accuracy for the second target when it was preceded by another attended target within a temporal distance of 100–400 ms (e.g., Broadbent & Broadbent, 1987; Raymond, Shapiro, & Arnell, 1992; Reeves & Sperling, 1986). This phenomenon of impaired information processing is called the Attentional Blink. Most authors investigating the AB hold post-perceptual processes such as working memory consolidation responsible for the performance decrease (e.g., Chun, 1997; Chun & Potter, 1995; Jolicoeur & Dell'Acqua, 2000; Olson, Chun, & Anderson, 2001; Vogel, Luck, & Shapiro, 1998). The *two-stage model* proposed by Chun and Potter (1995) assumes that the AB phenomenon traces back to capacity limitations at the second of two processing stages required for correct target report, namely, working memory consolidation. Following this model, a very broad but rough representation is built at the *first stage*, allowing the *detection* of target-defining features. Only at the *second stage* of information processing is a more durable and valid object representation created, involving consolidation into working memory allowing full *identification* of the object, which is a prerequisite for correct report. However, this stage operates rather slowly and serially: only after the first target has completely passed through this phase can the next target enter. As this second phase lasts longer than the presentation of items within the rapid serial string, subsequent items can enter the first, but not the second stage before processing is complete. The longer the second item must be preserved in the first stage, the higher the probability of losing its representation, causing lower report rates of T2 items if they appear within the temporal frame of stage two processing of T1 (see Potter, Staub, & O'Connor, 2002; Raymond, 2003; Zuvic, Visser, & DiLollo, 2000). This model is further supported by electrophysiological data (Luck, Vogel, & Shapiro, 1996; Vogel & Luck, 2002; Vogel et al., 1998).

The AB paradigm is useful for the study of cognitive biases in specific phobia because it allows us to answer the following questions: When we present individually threatening stimuli – what information is preferentially selected for processing at a higher level? Does the general rule ''first in, first out'' apply – implying that the first T1 item to enter stage 2 is completely processed before a subsequent T2 item can enter? Or can incoming threatening stimuli disrupt ongoing processing? Thus far, only a few studies have addressed the characteristics of the AB phenomenon with emotional materials. Smith, Most, Newsome, and Zald (2006), for instance, reported decreased report probability for neutral T2 pictures when these were preceded by aversively conditioned (but originally neutral) photographs. Manipulating T1 as either neutral or emotional, Arend and Botella (2002) compared the AB magnitude in low versus high-trait anxious participants. In contrast to Smith et al. (2006), they observed reductions in AB effect for emotional words in high-trait anxious only, indicating disorder-specific influence on the AB effect. However, in both of these studies, the valence of the first target was varied, which means that the duration of consolidation for emotional materials and subsequent encoding of neutral materials was investigated. Thus, these studies addressed whether the second stage as described by Chun and Potter (1995) is faster or slower for emotional materials, but not whether disorder-specific emotionality can affect general laws like "first in, first out". Keil and Ihssen (2004) investigated the AB phenomenon with neutral, pleasant, and unpleasant T2 verbs in rapid serial visual streams. Participants were asked to select the two green-colored target words from a string of otherwise white-printed distractors. With shorter T1–T2 distance, the accuracy in reporting T2 was reduced, which is the Attentional Blink phenomenon. Enhanced report rates for T2 (a reduction of the AB) were observed for all T2 that were rated as emotionally salient and highly arousing. The authors concluded that "affectively arousing information is selected preferentially from a temporal stream, facilitating processes such as working memory consolidation and action". Similar results were reported by Anderson (2005). While Keil and Ihssen (2004) found no influence of T2 valence on T1 report accuracy, Anderson (2005) found some evidence that negative, arousing T2 stimuli affect T1 performance.

However, neither study investigated whether individual differences in T2 salience were related to report probability of T1. When, for instance, the negative T2 stimulus depicts a spider – is the subsequent AB reduction related to the participant's anxiety for spiders? Or, in other words, when the AB mirrors the loss of information at a post-perceptual stage – does individual threat positively influence the preservation of information? To the best of our knowledge, only two studies have investigated the AB magnitude in relation to anxiety for T2 stimuli (de Jong & Martens, 2007; Fox, Russo, & Georgiou, 2005). While Fox et al. (2005) found no effects of facial T2 valence on T1 report accuracy in highly trait anxious individuals, de Jong and Martens (2007) reported reduced T1 report accuracy with angry T2 faces in both high and low socially anxious participants. The differences in these two studies regarding T1 effects so far allow no conclusions whether increased response rates for negative T2 are truly related to prioritized VWM consolidation at the expense of T1 or not. These differences might be related to very small sample sizes in both studies resulting in a general lack of power and, thus, a lack of group differences in de Jong and Martens' (2007) study. Moreover, neither study included neutral targets. Therefore, it is not clear whether an angry T2 is preferentially encoded at the cost of T1, or whether a positive T2 is less efficiently encoded in favor of T1.

In the present study, we attempted to overcome these limitations by testing a larger sample and by including a neutral T2 category. Only when biases occur exclusively in the presence of disorder-specific materials should they be considered relevant in the genesis and maintenance of the affliction. We investigated an anxiety disorder that has, thus far, not been investigated with an AB paradigm, namely, spider phobia. Here, the scope of fear is clearly limited to spiders. Thus, the selection of anxiety-specific materials is easy. In two AB experiments, participants were instructed to attentively follow a string of pictures and then report the two target items indicated by a brighter background. In Experiment 1, participants with varying levels of spider anxiety viewed rapid serial presentations of 15 mostly neutral images. The valence of the second target (T2) was varied, depicting either a neutral (mushroom), positive (blossom), or a negative image (spider). Additionally, the time between the two targets (T1 and T2) was varied in order to get information about the onset and duration of the AB under different valence conditions. We were interested in whether there was enhanced report for negative T2 and whether this advantage was related to the individual's spider anxiety. Furthermore, we were interested in T1 report deficiencies when negative T2 images were presented. In Experiment 2, we repeated the same paradigm, while modifying T2 type and participant characteristics: in addition to the negative "spider" stimulus, we presented pictures of snakes. Observers were either spider fearful or non-spider anxious, both without snake anxiety. This experimental design allows for conclusions regarding disorder-specific biases in the temporal processing of spiders and whether these effects appear only with spiders or also with other negative materials unrelated to the disorder.

## 1. Experiment 1: the Attentional Blink for emotional pictures in a random sample

In an AB task, the probability of reporting the second of two targets is reduced when it appears approximately

100–500 ms after the first. This has previously been explained by capacity limitations at the stage of working memory consolidation. However, research on attentional biases in specific phobia suggests that emotionally relevant stimuli are processed preferentially, presumably automatically (e.g., Williams, Mathews, & MacLeod, 1996). For evolutionary relevant materials, such as spiders or snakes, this effect occurs in all people, but is particularly strong for those who are afraid of the employed stimulus (e.g., Oehman, Flykt, & Esteves, 2001). The current study was designed to investigate whether such a bias occurs in an Attentional Blink paradigm. We sought to answer the following questions: (A) Is the Attentional Blink reduced in amplitude and duration when T2 depicts a spider compared to neutral or positive images? (B) If spider T2 images lead to reduced AB, is this reduction related to the individual's spider anxiety? (C) Does the presentation of spider T2 images influence the report accuracy for T1 in comparison to neutral and positive T2? For instance, does a spider image disrupt the rule "first in, first out" such that it is preferably processed at the expense of T1? (D) Is a lower T1 memorization after presentation of a spider T2 related to higher spider anxiety?

### *1.1. Methods*

#### *1.1.1. Participants*

Prior to the experimental sessions, interested students from several departments at Dresden University of Technology were asked to enlist their name and phone number. From these lists, 60 randomly chosen people were called and invited for testing. According to Cohen (1988), this sample size allows for the detection of medium-sized differences between means with a probability of $1 - \beta = .86$, and for the detection of medium-sized correlations with probability of $1 - \beta = .76$ (see Cohen, 1988, p. 31 and 87, respectively). To ensure that none of the participants had an aversion for neutral or positive T2 stimuli, we asked if they had any allergies or general antipathy for flowers or mushrooms; no participants were excluded for this reason. All candidates had high school degrees and were students of Dresden University of Technology. On average, the 51 women and 9 men were 20.9 years of age (S.D. = 2.3), all were without history of psychiatric disorder and had normal or corrected-to-normal vision. All volunteers were informed of their rights as experimental participants and gave their consent to participate in the study. In return for their participation, they received either course credit or a payment of €5. Participants with pronounced spider anxiety were told about behavioral therapy as a treatment option, and were given contact information of the outpatient university clinic.

#### *1.1.2. Materials and apparatus*

The experiment was controlled by MATLAB software using the Psychophysics Toolbox extensions (Brainard, 1997; Pelli, 1997). Stimuli were presented on a gray background on 17 in. monitors with a resolution of $1024 \times 768$ pixels. Responses were recorded via button press. The displayed elements included 84 square ($115 \times 115$ pixel) color images, made up of 40 neutral distractors, 32 neutral T1 (16 kitchen, 16 non-kitchen), 4 neutral T2 (mushrooms), 4 pleasant T2 (blossoms), and 4 unpleasant T2 items (spiders).

Pictures were chosen after extensive pretesting.[1] For the *T1 sample*, only neutral pictures having valence ratings not significantly different from the neutral mean (5.0) on the rating scale were employed. These were further divided into 16 "kitchen items" and 16 "non-kitchen items" based on agreement of at least 90% of the raters (most were classified with agreement of 95–100%). For the *T2 sample*, four mushroom images with neutral valence ratings, four blossom pictures with positive, and four spider items with negative valence ratings were selected. As *distractors*, 40 images with neutral valence that did not match any of the T2 categories were chosen (for example, see Fig. 1A).

#### *1.1.3. Procedure*

Prior to the experimental session, participants were informed about the general experimental procedure and filled out the "Spider Anxiety Screening" form (SAS, Rinck et al., 2002) and the German version of the "Fear of Spiders Questionnaire" (FSQ; Szymanski & O'Donohue, 1995; see Rinck et al., 2002). They were then given written instructions on the computer monitor instructing them to attend to the presented picture string and prepare for a memory test where they would make decisions about the two target items indicated by a bright-gray background. The importance of accuracy was emphasized. Additionally, participants viewed a schema of a sample

[1] Twenty individuals who did not participate in the experiments reported here rated a sample of 200 pictures. The sample included several variations of diverse potential T2 images (spiders, snakes, blossoms, wheels, mushrooms, fruit), several kitchen and non-kitchen items, and many additional images of varying appearance and valence. Each item was judged on 9-point scales regarding valence (from 1 very pleasant to 9 very unpleasant) and recognizability (from 1 very good to 9 very bad). Additionally, each item was classified as "definitely kitchen item" versus "definitely no kitchen item". Only images with mean recognizability ratings of 3 or less were used.

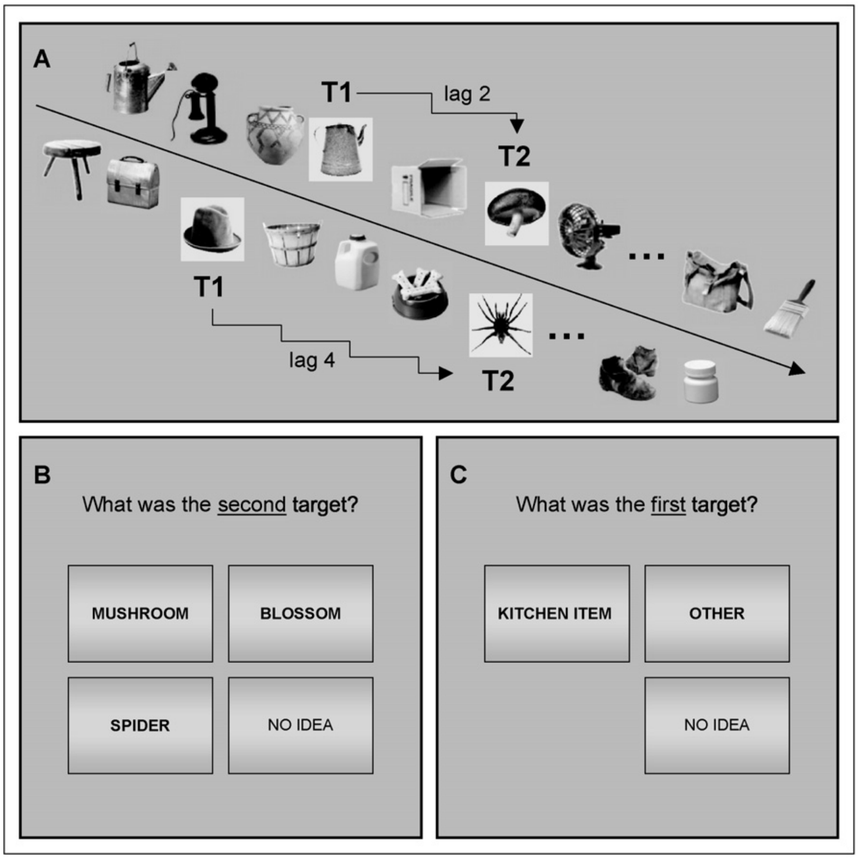


Fig. 1. Schematic depiction of the trial procedure in Experiments 1 and 2. (A) Participants viewed fifteen images, each presented for 80 ms. The task was to identify the two target items indicated by a brighter background. The upper row shows a neutral trial with a T1–T2 lag of 2. The lower row depicts a negative trial with a T1–T2 lag of 4. (B) After the presentation of the image string, participants decide by clicking on the display whether the second target was a mushroom, a blossom, or a spider. (C) Afterwards, identification of the first target as kitchen or non-kitchen item is requested. *Note*: Actual stimuli were in color.

trial including the response menus and an overview of the different picture types (e.g., kitchen items, blossoms) to become familiarized with the materials.

The computer screen was placed approximately 70 cm away from the participant. Each experimental trial started with the presentation of a black fixation cross on a gray background. After 500 ms, the rapid serial presentation of 15 images centered on the screen at a rate of 80 ms per picture with an ISI of 0 ms started. Trial by trial, the position of T1 within the picture series was randomly determined, occurring in equal measure at the string positions 3–8. The position of T2 was determined randomly using fixed T1–T2 lags of 1, 2, 3, 4, 5, or 6. A lag of 1, for instance, indicates that T2 will be presented directly after T1, equal to an SOA of 80 ms. Both the content of T1 and T2 were randomized. Within T1 images, kitchen and non-kitchen items were each displayed 50% of the time. Likewise, T2 depicted neutral (mushroom), positive (blossom), or negative (spider) items equally often. Additionally, 13 distractor images were randomly chosen from the pool of 40 items and randomly inserted into the remaining positions of the image string. Compared to the distractor items, both target items were characterized by a brighter gray background ($120 \times 120$ pixels). Two sample trials, showing both neutral and negative T2 images, are shown in Fig. 1. After the picture string, a blank gray screen was presented for 1000 ms to avoid memory masking by the onset of the response menus. The response menus for T2 (see Fig. 1B) and T1 (see Fig. 1C) were displayed one after another for at most 5000 ms each. Participants were first asked to indicate whether T2 had depicted a mushroom, a blossom, or a spider, and then to decide whether T1 had shown a kitchen or non-kitchen item by clicking on the corresponding button. In both response phases, an additional button could be selected to indicate that the observer did not know the correct response (“no idea”). Written feedback was provided on screen after each of the two

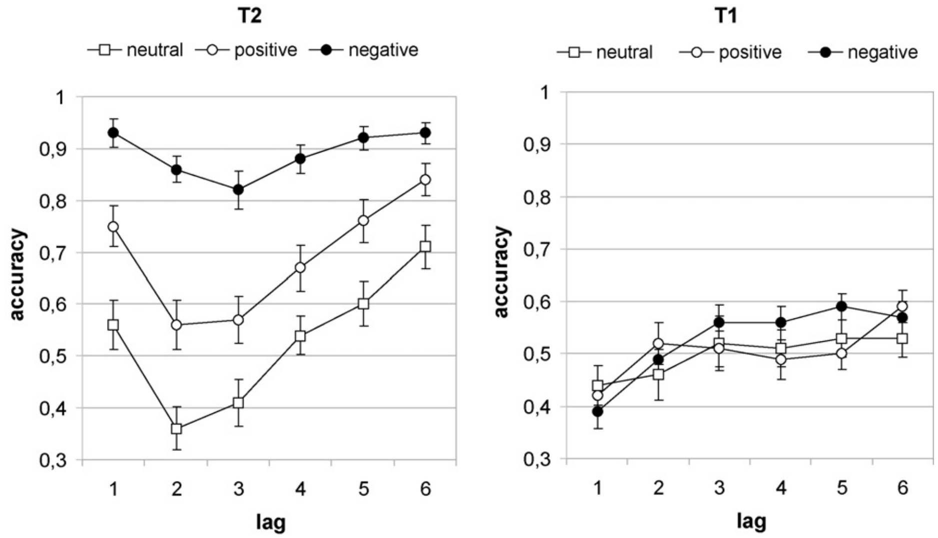


Fig. 2. Left panel: means (and standard error bars) for correctly reporting T2, dependent on its valence and lag in Experiment 1, for trials with a correct T1 response only. Right panel: means (and standard error bars) for correctly reporting T1, dependent on T2 valence and the lag in Experiment 1, for trials with a correct T2 response only.

responses. Participants initiated the next trial with a key press, and could thereby take breaks whenever needed. After the experiment, participants were debriefed. A complete session took approximately 40 min.

*1.1.4. Design*

The task followed a $3 \times 6$ factorial design with within-subjects factors "T2" (*neutral*: mushroom, *positive*: blossom, *negative*: spider) and "lag" (1, 2, 3, 4, 5, or 6). For each trial, T2 and lag were pseudo-randomly chosen by the MATLAB program. Each of the 18 possible combinations of the two factors was presented 10 times to each participant. Thus, they completed 180 experimental trials, preceded by 6 practice trials. For each factorial combination, we determined the mean accuracy in correctly identifying T2 provided that the T1 response was accurate and the mean accuracy in correctly reporting T1 for correct T2 trials.

*1.2. Results*

*1.2.1. Questionnaires*

The 60 participants revealed a mean SAS score of 12.1 (S.D. = 6.0) and a mean FSQ score of 27.9 (S.D. = 25.6), which is in line with mean scores previously reported by Rinck et al. (2002) in unselected samples.

*1.2.2. Experimental task*

Prior to statistical testing, practice trials were discarded from the data set. Following standard procedures of AB task analysis, we (A) calculated the T2 report accuracy for the different lag conditions in trials with correct T1 reports, (B) tested whether report accuracy for spider items correlated with the individuals' spider anxiety, and (C) calculated T1 report accuracy dependent on T2 type. Below, effect sizes are reported as Cohen's $f$ values (1988).

(A) *Is the Attentional Blink reduced in amplitude and duration when T2 depicts a spider compared to neutral or positive images*?In an initial analysis, mean accuracy for reporting T2 dependent on its valence and T1–T2 lag was calculated for trials with a correct T1 report. These values were subjected to a two-way ANOVA, including the factors "T2" (neutral: mushroom, positive: blossom, negative: spider) and "lag" (1–6). In addition, we calculated two-way ANOVAs including only two T2 pictures at a time to determine which picture types differed from each other. As each factorial combination of lag and T2 was presented only 10 times, some participants did not correctly report T1 in individual cells. In these cases, the calculation of valid T2 accuracies after correct T1 responses was not possible. Therefore, we refer herein only to the 48 participants with complete data across all factorial combinations.[2] The results are depicted in the left panel of Fig. 2.

[2] Analyses of the data for all participants without considering whether the T1 response was correct led to comparable results.

Participants performed better in detecting spider T2 pictures than positive or neutral T2 images, $F(2,94) = 90.24$, $p < .001$, $f = 1.39$, spider-positive: $F(1,47) = 45.68$, $p < .001$, spider-neutral: $F(1,47) = 180.99$, $p < .001$, and the accuracy for detecting positive T2 images was higher than for neutral T2 items, neutral–positive: $F(1,47) = 44.79$, $p < .001$. Accuracy was also lower in specific lag conditions, $F(5,235) = 28.21$, $p < .001$, $f = .78$. This was true for all T2 types, lag spider: $F(5,235) = 3.88$, $p < .01$, $f = .29$, lag positive: $F(5,235) = 12.82$, $p < .001$, $f = .52$, lag neutral: $F(5,235) = 15.12$, $p < .001$, $f = .56$. The lag effect was similar for positive and neutral T2, positive–neutral: $F(5,235) = .51$, $p = .766$, $f = .10$, but different for spider T2, spider-positive: $F(5,235) = 3.53$, $p < .01$, $f = .27$, spider-neutral: $F(5,235) = 5.16$, $p < .001$, $f = .33$.

Moreover, the significant interaction of lag and T2 type, $F(10,470) = 2.96$, $p = .001$, $f = .58$, suggests that the three valence conditions differed regarding onset, duration, and amplitude of the Attentional Blink. The left panel of Fig. 2 demonstrates that in all T2 conditions, report accuracy was lowest at lags 2 and 3, producing the AB characteristic U-shaped curves. However, the U-shape was less prominent in the spider condition. To determine whether there were any valence-related differences regarding the *onset* and *duration* of the Attentional Blink, for each valence condition paired *t*-tests were computed for all possible pairs of the first four lag conditions. In all valence conditions, accuracy at lag 1 was significantly higher than at lag 2 [spider: $t(47) = 2.08$, $p < .05$, $f = .20$, positive: $t(47) = 4.42$, $p < .001$, $f = .32$, neutral: $t(47) = 3.83$, $p < .001$, $f = .33$] and lag 3 [spider: $t(47) = 2.64$, $p < .05$, $f = .25$, positive: $t(47) = 4.34$, $p < .001$, $f = .30$, neutral: $t(47) = 3.15$, $p < .01$, $f = .24$], but did not differ anymore from accuracy at lag 4 [spider: $t(47) = 1.48$, $p = .146$, $f = .13$, positive: $t(47) = 1.81$, $p = .077$, $f = .14$, neutral: $t(47) = .29$, $p = .782$, $f = .04$]. In all valence conditions, there was no significant difference between the T2 accuracy at lags 2 and 3 [all $t(47) < 1.19$, all $p > .201$]. This implies that the encoding of T1 led to lower encoding probability for T2 when T2 appeared 160–320 ms after the onset of T1, independent of the valence of T2. Regarding the onset and duration of the AB, there seemed to be no differences between the three picture types. The calculation of the *quadratic contrasts* for the first four lag conditions, separately for each T2 condition confirmed AB effects for all valence conditions, as there were strong quadratic contrasts in the neutral curve, $F(1,47) = 28.08$, $p < .001$, $f = .77$, and in the positive condition, $F(1,47) = 17.67$, $p < .001$, $f = .61$, and also – although weaker – in the spider curve, $F(1,47) = 6.32$, $p < .05$, $f = .37$.

To test whether the three T2 conditions yielded differences in AB *amplitude*, we first calculated the *standard deviation* of the six mean accuracies yielded at each lag position, separately for each curve and each participant, as a parameter of the amplitude of AB effects. The standard deviations ($S.D._{neutral} = .24$, $S.D._{positive} = .22$, $S.D._{spider} = .12$) were then subjected to a one-way "T2" ANOVA. The standard deviations of the six lag means differed significantly between the three picture types, $F(2,94) = 21.36$, $p = .000$, $f = .67$, implying differences in the strength of the AB effect between the three valence conditions. Additional paired *t*-tests confirmed a similar AB amplitude in the neutral and positive condition, $t(47) = 1.41$, $p = .166$, $f = .13$, but a weaker AB in the spider condition, neutral-spider: $t(47) = -4.61$, $p = .000$, $f = .62$, positive-spider: $t(47) = -5.88$, $p = .000$, $f = .47$.

In an additional analysis, it was tested whether the onset of the Attentional Blink with spider T2 was related to the individuals' spider fear. Therefore, the additional measure "onset of the Attentional Blink" was defined, indicating whether the individual's recall accuracy of spiders declined at lags 1, 2, 3, 4, 5, 6, or not at all. Spearman's correlational analyses yielded no significant association between this onset of the Attentional Blink in spider trials and level of spider anxiety, neither for the SAS (Rho = −.17, $p = .26$) nor for the FSQ (Rho = −.01, $p = .93$).

(B) *If spider T2 images lead to reduced AB, is this reduction related to the individual's spider anxiety*?

To investigate whether there were any correlations between the participants' spider anxiety and their spider T2 performance in the Attentional Blink paradigm, we correlated the mean of the six means of the spider curve versus the mean of the first four means of the spider curve with the individual's SAS and FSQ scores in Pearson's correlation analyses. These calculations revealed no significant correlations, with all $r < .106$ and all $p > .474$. In addition, we correlated the standard deviation of the six lag points of the spider curve versus the standard deviation of the first four means of the spider curve with the self-reported spider anxiety. The participants' AB effect and their self-reported spider anxiety did not correlate, all $r > -.105$, all $p > .386$.

(C) *Does the presentation of spider T2 images influence the report accuracy for T1 in comparison to neutral and positive T2*?

To test whether the content of T2 items influenced the report accuracy of T1, we conducted a two-way ANOVA with the independent measures "lag" and "T2" and the dependent measure "T1 accuracy in correct T2 trials". Again, data from three participants did not contain all necessary values. Therefore, the analysis was based on the 45 participants with full set of results. Means are depicted in the right panel of Fig. 2. Calculations revealed that the content of the T2 image did not affect the report probability of T1, T2: $F(2,88) = 1.33$, $p = .269$, $f = .18$, T2 × lag: $F(10,440) = 1.11$, $p = .354$, $f = .18$, but that independent of T2 type, T1 was missed more often with short lags, lag: $F(5,220) = 7.65$, $p < .001$, $f = .42$. This was confirmed by an additional ANOVA excluding lag 1 data, which no longer showed significant lag effects, $F(4,176) = 2.24$, $p = .067$, $f = .23$.

(D) *Is a lower T1 memorization after presentation of a spider T2 related to higher spider anxiety*?

To find out whether memory accuracy for neutral T1 items before a spider T2 was related to spider anxiety, we calculated (a) the mean of the T1 report accuracies at the six lag conditions and (b) the mean at lag conditions 1 and 2, which proved to be most prone to T2 onset effects. These values were, together with individual SAS and FSQ scores, subjected to Pearson's correlation analyses. Calculations revealed no correlations of spider anxiety with either the T1 mean depending on all six lag positions, SAS: $r = -.080$, $p = .601$, FSQ: $r = .038$, $p = .803$, or with the T1 mean depending on only the first two lag positions, SAS: $r = .055$, $p = .718$, FSQ: $r = .127$, $p = .406$.

### *1.3. Discussion*

In Experiment 1, we investigated whether a spider T2 is associated with a different AB pattern than for a positive or a neutral T2, whether this difference is related to the individuals' spider anxiety, and whether T1 report accuracy is lower when it is followed by a spider. We found significant lag effects in all T2 conditions, causing U-shaped courses in each. For all T2 types, report accuracy was lowest between 160 and 320 ms SOA, which is in line with the literature investigating AB with simple letters (e.g., Chun & Potter, 1995) or words (e.g., Anderson, 2005). Thus, there were no differences in the onset and duration of the AB in the three picture conditions. However, the magnitude of the AB was significantly lower in the spider condition, while the AB amplitudes in the positive and neutral T2 condition did not differ from each other. This effect of a reduced AB in spider curves did not correlate with individual spider anxiety. Spiders were generally more likely to be successfully reported than neutral or positive T2 pictures, but accuracy to spider T2 did not correlate with individual spider anxiety. Additionally, the valence of T2 did not affect report accuracy for T1, nor did T1 report accuracy in spider trials correlate with spider anxiety. T1 report accuracy was in general reduced with small T1–T2 lags, which is in line with the results reported by Anderson (2005). Summarizing, Experiment 1 suggests that the evolutionary meaning or general negativity of items affects the AB phenomenon. In contrast, the individual threat value of a stimulus did not seem to increase its probability of being promoted to a higher processing level for consolidation. The data indicate no processing preference for spiders at the cost of other items undergoing higher processing. A deeper discussion of the results follows in Section 3.

## 2. Experiment 2: the Attentional Blink for spiders and snakes in spider fearfuls versus non-anxious controls without snake anxiety

In Experiment 1, despite sufficient statistical power, we found no correlations between the AB reduction by spiders and individual spider anxiety, nor did we find correlations between T1 accuracy in spider trials with spider fear. However, the SAS and FSQ scores of the participants of Experiment 1 indicate that the sample included predominantly individuals with low or medium levels of spider fear and barely any highly fearful participants. Thus, the results can hardly be generalized to spider phobics. Therefore, in Experiment 2, only participants with either very low or very high, clinically relevant spider anxiety was tested to see if report accuracy for T2 spiders and T1 items in spider trials would differ between the two groups. As earlier studies on spatial VWM biases in spider anxiety suggested disorder-specific enhancement for spider images, we sought to determine whether this difference would also occur in a temporal VWM paradigm. We further tested whether any group differences in consolidation of T2 spiders would not only be disorder-specific, but also materials-specific. Therefore, the negative T2 item in this experiment included both a disorder-relevant spider, feared by only one of the groups, and a generally negative snake, feared by none of the participants. In sum, the following research questions were addressed: (A) Do spider fearfuls show higher report accuracy for spider T2 than non-anxious controls? (B) If so, is this advantage specific to the feared spiders, that is, are there no group differences in reporting snake T2? (C) Do spider fearfuls reveal lower report accuracy for the T1 image in spider T2 trials? (D) If so, does this group difference occur with spiders, but not with snakes?

## *2.1. Methods*

### *2.1.1. Participants*

Thirty-one spider fearfuls (SFs) and 36 non-anxious controls (NACs), both without snake anxiety, participated in the experiment.[3] According to Cohen (1988), this sample size allows for the detection of medium-sized effects with power of $1-\beta = .62$, and large effects with $1-\beta = .93$ (see Cohen, 1988, p. 30). Potential participants were preselected in classes at several departments at Dresden University of Technology with the German ‘‘Spider Anxiety Screening’’ (SAS, Rinck et al., 2002) and the corresponding German ‘‘Snake Anxiety Screening’’ (SCANS, Reinecke, Becker, & Rinck, submitted for publication). Both four-item instruments assess the DSM criteria for specific phobia, namely ‘‘anxiety’’, ‘‘physiological activation’’, ‘‘avoidance’’, and ‘‘impairment’’. As it is easy to avoid spiders and snakes in Northern Europe and, consequently, impairments are rarely reported by anxious persons, no importance was attached to the ‘‘impairment’’ item in the prescreening analyses. Students with scores lower than 5 or higher than 14 on the three remaining items of the spider screening (SAS) and scores lower than 5 on the first three items of the snake screening (SCANS) were invited for further interviews and testing.

Before the experiment, participants were screened for alcohol or drug abuse, extreme stress, depression and psychosis. Potential participants were questioned regarding everyday stress, use of pharmaceuticals and drugs and the extent of their alcohol use. To exclude depressed students, the German FDD-DSM-IV inventory (Kuehner, 1997), which is a translation of the ‘‘Questionnaire for Depression Diagnosis’’ (Zimmermann, Coryell, Wilson, & Corenthal, 1986) was conducted. Moreover, volunteers completed the Trait form of the German State-Trait Anxiety Inventory (STAI; Laux, Glanzmann, Schaffner, & Spielberger, 1981) as well as the State form (once before and once after the experiment). Additionally, the psychosis section of the F-DIPS (Margraf, Schneider, Soeder, Neumer, & Becker, 1996), the German version of the ADIS (DiNardo, Brown, & Barlow, 1994), was applied. None of the volunteers had to be excluded due to suspicion of drug abuse, depression, or psychotic tendencies.

Afterwards, spider and snake anxiety were carefully measured: participants completed German versions of the ‘‘Fear of Spiders Questionnaire’’ (Szymanski & O’Donohue, 1995; see Rinck et al., 2002) and the ‘‘Snake Anxiety Questionnaire (SNAQ; Klorman, Hastings, Weerts, Melamed, & Lang, 1974; see Reinecke et al., submitted for publication). Trained interviewers assessed volunteers on DSM-IV criteria for specific phobia of spiders and snakes. For that purpose, the International Diagnosis Checklist for DSM-IV (ICDL; Hiller, Zaudig, & Mombour, 1997) was used, enlarged by the eight-stage assessment scales of the F-DIPS (Margraf et al., 1996). Only candidates fulfilling none of the DSM-IV criteria for snake phobia participated in the experimental task. Additionally, they had to meet criteria for one of the spider anxiety groups: for the non-anxious control group (NAC), they were not allowed to fulfill any of the DSM-IV criteria for specific spider phobia as assessed by the ICDL, and had to have an FSQ score below 11. Participants in the spider fearful group (SF) had to reach an F-DIPS ‘‘fear’’, ‘‘physical activation’’, and ‘‘avoidance’’ score of at least 4 each and a minimum FSQ score of 30. Eight of the 31 SFs fulfilled all DSM-IV criteria for a specific phobia of spiders, while the rest met all criteria except criterion E (significant impairment in everyday life).

The SF sample and the NAC group were matched for age, gender, and educational level. All candidates had high school degrees and were students of Dresden University of Technology. On average, the 31 female and 5 male members of the NAC group were 22.5

[3] Originally, 34 SF were tested. The data of one of these participants had to be removed from the data set due to a heightened snake anxiety score revealed in the SCAF. In two other cases, technical problems led to incomplete data recording.

Table 1
Mean questionnaire scores (means, standard deviations, *t*-tests) in the two experimental groups, calculated for all participants in Experiment 2

| | Non-anxious controls ($N = 36$) | Spider fearfuls ($N = 31$) | Significance of *t*-test (d.f. = 67) |
|---|---|---|---|
| Age | 22.5 (3.5) | 21.4 (2.5) | n.s. |
| SAS | 1.6 (1.6) | 17.9 (3.2) | .001 |
| FSQ | 1.8 (2.6) | 63.5 (17.3) | .001 |
| SCANS | 1.8 (1.6) | 2.4 (2.0) | n.s. |
| SCAF | 3.4 (2.0) | 3.9 (2.6) | n.s. |
| FDD | 2.9 (2.9) | 5.1 (3.9) | .05 |
| STAI-T | 36.1 (7.0) | 38.7 (6.6) | n.s. |
| STAI-S pre-experimental | 32.8 (4.9) | 38.8 (8.9) | .001 |
| STAI-S post-experimental | 32.4 (6.5) | 37.3 (7.1) | .01 |

years of age (S.D. = 3.5), while the 27 female and 4 male SF participants had a mean age of 21.4 years (S.D. = 2.5). All volunteers had normal or corrected-to-normal vision. All were informed of their rights as experimental participants and gave their consent. The participation was honored with course credit or payment of €5.

### 2.1.2. Materials, apparatus, and procedure

The experiment was nearly identical to Experiment 1. The only extension was a second negative T2 category, the snake images. We selected four pictures of dark-colored snakes from the picture pool rated as described above. Only images with a recognizability rating of at most three and a negative valence rating were included. The response menus were changed slightly with removal of the "no idea" buttons and addition of a "snake" button in the T2 response menu. However, participants were explicitly encouraged to avoid guessing.

### 2.1.3. Design

Statistical analyzes are based on a $2 \times 4 \times 6$ factorial design with the between subjects factor "group" and the within-subjects factors "T2" (*neutral*: mushroom, *positive*: blossom, *negative*: snake, *disorder-specific negative*: spider) and "lag" (1, 2, 3, 4, 5, or 6). For each trial, T2 and lag were pseudo-randomly chosen by the MATLAB experimental program. Each of the 24 possible combinations of the two within-subjects factors was presented 10 times to each participant. Thus, they completed a total of 240 experimental trials, preceded by 6 practice trials. For each factorial combination, we computed two critical values: (1) the mean accuracy in correctly identifying T2 provided that the T1 response was accurate in order to determine whether fearfuls and non-fearfuls would differ in reporting spider T2, but not snake T2. (2) The mean accuracy in correctly identifying T1 in dependence of a correct T2 response to determine whether fearfuls and non-fearfuls would differ in T1 report on spider trials, but not on snake trials.

## 2.2. Results

### 2.2.1. Questionnaires

The mean scores, standard deviations, and significance of *t*-tests for age and questionnaire scores are shown in Table 1. Snake anxiety scores on the SCAF were comparably low in both groups. Trait anxiety scores on the STAI-T fell within the normal range and did not differ between the groups. However, the groups slightly differed regarding depression scores on the FDD and pre-experimental and post-experimental state anxiety with higher scores in the SF group. Mostly, these values fell within normal range and therefore should not confound interpretation of the results reported below. We observed heightened FDD scores in three of the SF participants. However, a supplementary analysis regarding the experimental results showed that the FDD scores did not correlate with the effects reported later, but only the FSQ score.

### 2.2.2. Experimental task

(A and B) *Do spider fearfuls show higher report accuracy for spider T2 than non-anxious controls? If so, is this advantage specific to the feared spiders*?

For trials with a correct T1 response, we calculated mean accuracy in reporting T2 targets dependent on their valence and the lag condition for each participant. These values were subjected to a three-way repeated measures $2 \times 4 \times 6$ ANOVA for the within-subjects factors "T2" (neutral: mushroom, positive: blossom, negative: snake, disorder-specific negative: spider) and "lag" (1–6), and the between-subjects factor "group". The results are depicted in Fig. 3. Again, there were cases in which a person was completely unable to reproduce T1 correctly for a specific factorial

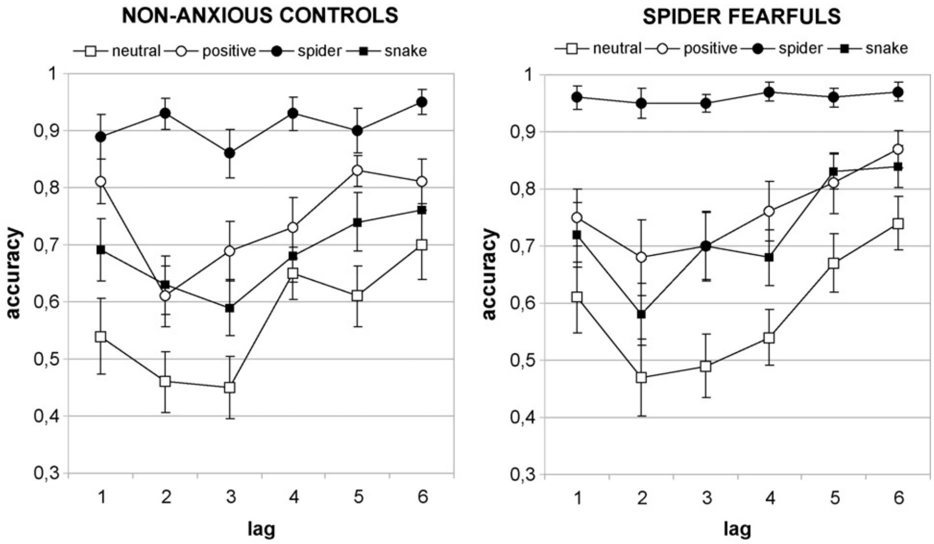


Fig. 3. Means (and standard error bars) for correctly reporting T2 after a correct T1 response in Experiment 2. Accuracy values for T2 are depicted dependent on its valence and the lag, separately for the two groups.

combination, making it impossible to calculate a valid accuracy value for T2. Therefore, this analysis is based only on participants that did not produce any empty cells.[4] The age and questionnaire differences between the remaining 26 SF and 28 NAC mirror the results presented in Table 1. As in the previous experiment, accuracy in reporting T2 depended on its valence, $F(3,156) = 83.45$, $p < .001$, $f = 1.28$, and on the lag condition, $F(5,260) = 18.74$, $p < .001$, $f = .61$, and there were differences between the four T2 picture types with regard to the AB, $F(15,780) = 2.49$, $p = .001$, $f = .23$. In contrast, the complete ANOVA revealed no differences between the groups, group: $F(1,52) = .98$, $p = .327$, $f = .14$, group × lag: $F(5,260) = .76$, $p = .583$, $f = .10$, group × T2: $F(3,156) = .25$, $p = .860$, $f = .10$, group × T2 × lag: $F(15,780) = 1.02$, $p = .435$, $f = .14$. However, calculating the same ANOVA including only the T2 conditions neutral, positive, and snake, suggested similar lag patterns in these three conditions and a differing lag pattern only in the spider condition, lag × T2: $F(10,520) = 1.15$, $p = .835$, $f = .10$, lag: $F(5,260) = 18.81$, $p < .001$, $f = .61$, T2: $F(2,104) = 26.85$, $p < .001$, $f = .72$.

Additional three-way ANOVAs including only two T2 types at one time revealed better accuracy for positive T2 than for snakes, $F_{\text{positive-snake}}(1,52) = 4.65$, $p < .05$, $f = .29$, better report accuracy for snakes compared to neutral images, $F_{\text{neutral-snake}}(1,52) = 24.11$, $p < .001$, $f = .69$, and the highest accuracy for spider images, $F_{\text{positive-spider}}(1,52) = 64.29$, $p < .001$, $f = 1.11$, without any group differences, all $F < .52$, all $p > .476$.

Additional "lag" × "group" analyses, separately for each T2 picture type, revealed marginally better spider detection in the SF group compared to the NAC group, $F(1,52) = 3.23$, $p = .078$, $f = .25$, but no group differences regarding the neutral condition, $F(1,52) = .13$, $p = .724$, $f = .00$, nor the positive condition, $F(1,52) = .11$, $p = .737$, $f = .00$, nor the snake condition, $F(1,52) = 1.03$, $p = .316$, $f = .14$. Without group differences, accuracy was similar at all lag positions of the spider curve, group × lag: all $F(5,260) < 1.05$, all $p > .390$, lag: $F_{\text{spider}}(5,260) = 1.33$, $p = .252$, $f = .18$, but differed depending on the lag in the three remaining valence conditions, $F_{\text{neutral}}(5,260) = 9.66$, $p < .001$, $f = .44$, $F_{\text{positive}}(5,260) = 7.32$, $p < .001$, $f = .37$, $F_{\text{snake}}(5,260) = 6.56$, $p < .001$, $f = .35$.

In a second analysis, the standard deviations of the six lag means (used as a measure of the AB effect) of each T2 curve and each participant were subjected to a two-way ANOVA with the factors "T2" and "group". Results (SF: $\text{S.D.}_{\text{neutral}} = .24$, $\text{S.D.}_{\text{positive}} = .20$, $\text{S.D.}_{\text{spider}} = .06$, $\text{S.D.}_{\text{snake}} = .23$; NAC: $\text{S.D.}_{\text{neutral}} = .22$, $\text{S.D.}_{\text{positive}} = .20$, $\text{S.D.}_{\text{spider}} = .10$, $\text{S.D.}_{\text{snake}} = .19$) indicated that in both groups, AB effects were significantly lowest in the spider condition, T2: $F(3,156) = 47.66$, $p < .001$, $f = .96$, SF: all $t_{\text{spider-other}}(25) > 7.91$, $p < .001$, NAC: all $t_{\text{spider-other}}(27) > 5.21$, $p < .001$. In addition, the AB effect in spider curves was slightly smaller in the SF group than the NAC group, group × T2: $F(3,156) = 3.23$, $p < .05$, $f = .25$, yielding

[4] The analyses of the data of all participants independent of a correct T1 response led to comparable results.

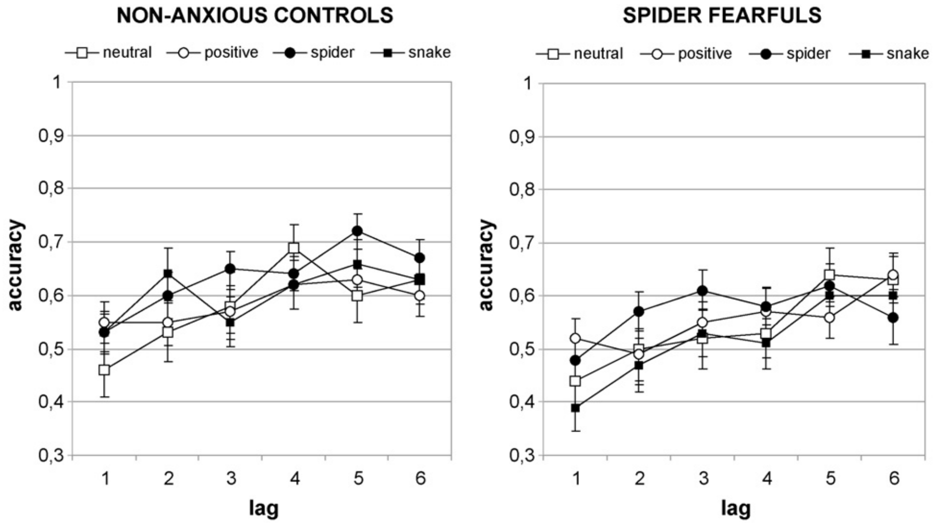


Fig. 4. Means (and standard error bars) for correctly reporting T1, dependent on T2 valence and lag in Experiment 2, for trials with a correct T2 response only, separately for the two groups.

a flatter spider curve in SFs than in NACs. Considering only the first four lag conditions of each curve for the calculation of the standard deviations led to similar results.

(C and D) *Do spider fearfuls show lower report accuracy for the T1 image in spider T2 trials? If so, does this group difference only occur with spiders, but not with snakes*?

This calculation is based on the 24 SF and 24 NAC who did not produce any empty cells. In this analysis, we tested whether the accuracy in reporting T1 depended on the valence of T2 and group. Therefore, we computed a three-way ANOVA with the factors ‘‘lag’’, ‘‘T2’’, and ‘‘group’’. Results are depicted in Fig. 4. A lag effect was observed, which was independent of group or T2 type: T1 accuracy decreased with decreasing lag, lag: $F(5,230) = 12.69$, $p > .001$, $f = .53$, lag × group: $F(5,230) = .75$, $p = .587$, $f = .14$, lag × T2: $F(15,690) = .98$, $p = .480$, $f = .14$, lag × group × T2: $F(15,690) = 1.02$, $p = .436$, $f = .14$. In both groups, T1 performance was higher for spider T2, T2: $F(3,138) = 3.06$, $p < .05$, $f = .25$, T2 × group: $F(3,138) = 1.22$, $p = .306$, $f = .18$, and similar for neutral, positive, and snake T2, $F(2,92) = .21$, $p = .809$, $f = .10$. In general, NAC T1 performance was similar to that of SF, group: $F(1,46) = 3.51$, $p = .067$, $f = .27$.

### 2.3. Discussion

With Experiment 2, we studied whether two extreme groups with low versus high spider anxiety would exhibit any differences in the AB effects yielded with threatening T2, and if so, whether this group effect would occur with disorder-specific threatening materials only, or also with other negative stimuli such as snakes. Both groups reported spiders significantly better than blossoms, blossoms significantly better than snakes, and snakes significantly better than mushrooms. Regarding the latter three T2 conditions, we observed no differences in the lag patterns, whereas in both groups, there seemed to be no lag effects at all for spider T2, which is in contrast to Experiment 1. While the data indicated no group differences in report accuracy regarding neutral, positive, and especially snake items, we observed a slight group difference in the identification of a spider T2, with advantages in the spider fearful group. Analyses of the ‘‘flatness’’ of the T2 curves revealed that both groups, but especially the SF group, showed lowest lag dependence in the spider curve. In addition, both groups unexpectedly revealed higher T1 accuracy in spider T2 trials. To summarize, the data hint at the relevance of the individual threat value of an item for the report probability during the AB temporal frame, but do not indicate relevance of the individual threat value of an item for the report probability of the target item seen before.

## 3. General discussion

In two studies, we investigated the Attentional Blink in picture strings with T2 materials of differing valence. In Experiment 1, T2 depicted either a neutral mushroom image, a positive blossom picture, or a negative spider image. While on average, spiders were reported with a higher accuracy than blossoms, and blossoms were more often correctly reported than mushrooms, the AB typical U-shaped curve occurred in all valence conditions, implying high accuracy at lag 1, but significantly reduced report accuracy at lags 2 and 3. That is, an AB appeared at about 160–320 ms after the onset of the first attended target without any differences between the three valence types regarding onset and duration. While the magnitude of this AB was similar for neutral and positive T2, it was reduced for spider T2. We observed no correlation between the flatness of the spider curve, that is, the reduction of the spider AB effect, and an individual's spider anxiety. The T2 valence had no influence on the report probability of T1, and the T1 accuracy in spider T2 trials was not correlated with individual spider anxiety. Rather, T1 accuracy was lower at lags 1 and 2 in all T2 conditions.

In Experiment 2, we tested spider fearfuls and non-anxious controls, both without snake anxiety, for two negative T2 conditions, a disorder-related spider image and an unrelated snake image. In both groups, spiders were better reported than positive items, these were slightly better identified than snakes, and neutral images had the lowest report probability. The mean accuracy in reporting spider T2 was marginally higher in SF. There were no differences in report accuracy for snake T2 between groups. Moreover, the data revealed similar lag patterns in the positive, the neutral, and the snake condition in both groups, and no significant lag effects at all in the spider condition, again in both groups. Nevertheless, spider T2 curves were significantly flatter in the SF group compared to the NAC group as indicated by the standard deviation of the six lag conditions. In addition, both groups showed higher T1 accuracy with spider T2 compared to other T2.

What do these data tell us about the relevance of emotionality of an item – especially its individual threat value – for the magnitude of the AB, and about the existence of temporal working memory biases in specific anxiety? First, we can conclude that stimuli with a positive or negative valence are *in general* reported more often than neutral stimuli. That is, participants viewing a very rapid serial presentation of images preferably select emotional stimuli for higher level processing. This is in line with processing theories postulating that emotional information is quickly and automatically filtered (for a review, see, for instance, Williams et al., 1997). However, Experiment 1 demonstrated that both neutral and emotional stimuli are prone to AB effects in a similar manner: independently of its emotionality, a target is reported with lower probability when it occurs within the AB temporal frame of 160–320 ms after the onset of another, attended target. Regarding the two-stage model of Chun and Potter (1995), this observation implies that higher processing of an emotional T2 at least partially uses the same resources as the higher processing of neutral items: while T1 is still in the consolidation phase, T2 has to be held in stage 1, which is more prone to forgetting, producing an AB phenomenon. However, in both experiments, the AB magnitude was lower for spiders at all anxiety levels. This might on the one hand imply that, when the first target was still under higher processing, the stage 1 representation of a T2 spider was either *more durable* than the *stage 1 representation* of a mushroom or a blossom T2 and, thus, was more likely to survive the processing delay. On the other hand, it might suggest that in the consolidation of spider images, *less resources* are required or some *additional, presumably automatic processing resources* are activated. Further experiments are required to test the validity of these competing explanations. The advantage to spider T2 at all anxiety levels is in line with the preparedness theory (Seligman, 1971), assuming that humans are predisposed to be alert to situations or animals that endangered survival during our evolutionary history. Possibly, some kind of internal representation of phylogenetically ‘‘dangerous’’ objects and situations accelerates the creation of a spider T2 representation. This will be an interesting avenue for further research.

Earlier research already suggests that emotional materials are preferentially selected from a stream of information for encoding in working memory (Anderson, 2005; Keil & Ihssen, 2004), and that the encoding of these items takes less time (Arend & Botella, 2002). Getting back to our earlier questions—how preferential is this preferential processing of threatening stimuli in specific anxiety? Is the reduction of the AB magnitude related to individual anxiety regarding the emotional stimuli? Does this possible advantage come at the expense of items currently undergoing processing, resulting in premature ejection from being processed? And if so, is it related to the individual threat value of an item?

Our data suggest that for samples with a normal distribution of spider anxiety as in Experiment 1, the AB magnitude is not related to spider anxiety, and advantages for negative T2 items are not related to T1 costs. However, it seems that for anxiety states with clinical relevance, AB patterns are different, implying the existence of *disorder-specific biases* in anxiety disorders. First, in highly spider fearfuls, the AB magnitude is additionally reduced compared to non-anxious controls. This enhanced encoding of spider T2 in spider fearfuls might be due to their experience with spider materials. According to Cave and Batty (2006), phobics are faster at identifying feared stimuli due to a *better representation of phobic materials* as a result of their regular preoccupation with those items. Possibly, such an additional internal representation of the ''feared'' spider is involved in the enhanced identification of spider T2 within the rapid stimuli stream. In contrast, both high and low spider anxiety participants exhibited higher T1 performance with spider T2. Together with the data of Experiment 1, this indicates that at all anxiety levels, the appearance of a spider T2 does not lead to the interruption of ongoing processing of a T1 item. The *processing of an item is not cancelled in favor of a spider item*, and the general rule ''first in, first out'' seems to be valid for both threatening and neutral items. At extremely high and low levels of anxiety, the onset of a spider T2 seems to evoke additional resources for completion of T1 processing. This implies that at particularly high and low anxiety levels, negative T2 images may require less processing resources for their own encoding.

However, some inconsistencies in spider AB results between Experiments 1 and 2 point to methodological differences and therefore, interpretational limitations. Experiment 1 yielded significant lag effects for spider T2, while Experiment 2 yielded no lag effects for spider T2 at all. Moreover, missing T1 and T2 enhancement effects with snake T2 compared to spider T2 in Experiment 2 also requires explanation. Several explanations may seem initially plausible for the lack of AB effects on spider T2 in Experiment 2, but do not hold upon closer examination: (a) one might argue that the missing ''no idea'' button in Experiment 2 may have encouraged guessing in trials where observers did not identify a T2, and that they chose the spider button, as extensive prescreening for spider anxiety might have primed insights into study interests. However, as prescreening for snake anxiety was comparably extensive, we should have observed similar AB effects in the snake curve as well; (b) participants may have responded with the spider button when they merely noticed ''something dark''. But as only one of the four spiders was definitely darker than the snakes, the difference between the snake and the spider curve should not be that prominent. From earlier studies investigating the AB with emotional words as T2 (e.g., Anderson, 2005; Keil & Ihssen, 2004) we know that it is not merely stimulus valence that reduces AB effects, but primarily the arousal value of the target which is responsible. A closer inspection of our own stimuli reveals that the most important difference between spiders and snakes (as well as all other objects) is that spiders were depicted close to their natural size, while the others were reduced in size. This may have produced less arousal for snakes, as compared to spiders. Unfortunately, we did not collect arousal ratings for our stimulus materials and therefore cannot answer this question. However, these effects, relevant or not, provide no explanation for why we observed spider T2 lag effects in Experiment 1, but not in Experiment 2. One could argue that only individuals with medium, non-extreme anxiety scores, show AB effects to the threat stimulus.

Another limitation of the current results exists in low average report performance for T1 items. While earlier studies report T1 accuracies of 80–90% (e.g., Fox et al., 2005; Keil & Ihssen, 2004), we observed T1 accuracies of only 50–60%. As mentioned above, we found similar T2 results regardless of whether or not incorrect T1 responses were included in the analysis. Nevertheless, the categorization task for T1 chosen in this study may have been overly complex for performance at such short presentation times. Further research should test this assumption by employing a less demanding T1 task.

In addition, one needs to keep in mind that in Experiment 2, an analogue participant sample was tested. Although the spider fearfuls fulfilled relevant diagnostic criteria, they were not patients seeking treatment. Previous research suggests that it might be relevant whether treatment seekers versus analogue participants are tested (e.g., Pérez-López & Woody, 2001; Sawchuk, Meunier, Lohr, & Westendorf, 2002), because cognitive biases may be intensified in patients. It would be worthwhile to repeat Experiment 2 with treatment-seeking spider fearfuls to determine whether group differences would be even more pronounced than in the current study.

Despite these limitations, the current study adds to the growing literature on working memory biases in specific anxiety. Cognitive biases are relevant maintaining factors in the pathogenesis of anxiety disorders, and it seems that disorder-relevant threat is not only preferentially processed at the level of attention, but also at the level of working memory. There is evidence that spider fearfuls reveal spatial VWM biases for threatening materials, and there is evidence suggesting that this bias is based on automatic processing of spiders (Reinecke et al., 2006). In addition, the present study suggests that fear of spiders might also be related to temporal working memory biases, implying disorder-specific enhanced working memory encoding of spider T2 in an AB task. Interestingly, the enhanced encoding does not seem to occur at the expense of T1 processing.

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