Out of sight, but still in mind: Electrocortical correlates of attentional capture in spider phobia as revealed by a ‘dot probe’ paradigm

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ABSTRACT

The current investigation focused on attentional processes in spider phobia. Twenty phobics and 20 controls performed a dot-probe task while event-related potentials were recorded. In each trial they viewed a picture pair (a spider or a generally disgust eliciting picture that was paired with a neutral picture) for either 100 or 1500 ms. After the offset a visual probe (a dot) was presented either at the previous position of the emotionally relevant or the neutral slide and participants were asked to indicate with a button press whether the dot had been presented on the left or the right side of the screen. Results revealed a modulation of the centro-parietal P300 (340–500 ms after picture onset). Amplitudes were higher when the dot replaced a spider than when it replaced a neutral picture. This was phobia-specific, as it was only present in phobics and did not appear in response to disgust pictures. Moreover, the modulation could only be shown for short presentation times. The results are interpreted to reflect motivated attention in spider phobia, if disorder-relevant and neutral pictures are shown simultaneously. As the modulation of the P300 was found after picture offset, attentional allocation seems to be persist after the phobic object is no longer present.

1. Introduction

With a point prevalence of 3.5% (Fredrikson, Annas, Fischer, & Wik, 1996) one of the most common subtypes of specific phobia is the fear of spiders, which mainly affects women. Diagnostic criteria of spider phobia according to DSM-5 (American Psychiatric Association, 2013) include the presence of an immediate and intense fear response during exposure to spiders (e.g., increases in heart rate and electrodermal activity), anxious anticipation, and pronounced avoidance of spiders leading to severe restrictions in daily routine. Although fear seems to be the main motivator for phobic avoidance, there is also evidence that the spider might represent a disgusting stimulus for patients, they do not want to get into close contact with. According to Davey (1994) this possibly stems from the association of spiders with illness, which was present in European cultures from the tenth century onward. Moreover, spider phobics relative to healthy controls have repeatedly been found to be prone to disgust, if confronted with potential disgust-eliciting situations (independent of spiders; for a review, see Olatunji, Cisler, McKay, & Phillips, 2010).

Biased processing of threat-related information has been discussed to play a central role in the etiology and maintenance of anxiety disorders (for a review, see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van Izendoorn, 2007). Attentional biases include facilitated attention to, difficulties in disengaging attention away from, or attentional avoidance of threat. In general, anxious individuals are more sensitive to fear-relevant stimuli in the environment, leading to hypervigilance towards threat during early, automatic stages of processing (Williams, Watts, MacLeod, & Mathews, 1997). This has also been reported for spider phobics (e.g., Mayer, Muris, Vogel, Nojoredjo, & Merckelbach, 2006). According to Williams et al. (1997), in anxious individuals attention is directed towards threat during initial and automatic stages of processing. In contrast, there are research groups suggesting that anxiety has only little impact on initial threat detection, but modulates the maintenance of attention to threat, leading to problems in disengaging attention from threat stimuli (Fox, Russo, Bowles, & Dutton, 2001). Furthermore, there is evidence, that attention is directed away from them during later, voluntarily controlled stages of processing (Williams et al., 1997). In fact, the inhibition of a deeper processing of threat-related information,
reflected by avoidance behavior when confronted with threatening stimuli, is regarded to be the core symptom of anxiety disorders (Foa & Kozak, 1986).

One possibility to study selective attention to threatening stimuli in patients with anxiety disorders is the ‘dot-probe task’ (for a review, see Frewen, Dozois, Joanisse, & Neufeld, 2008). In this task, participants are presented with a ‘cue’ (two pictures varying in emotional significance, e.g., fear vs. neutral). The pictures are shown simultaneously in different locations of a computer screen (e.g., on the left and right side). Afterwards, a ‘probe’ (e.g., a white dot) appears on the screen replacing one of the pictures. In a ‘valid’ trial the dot replaces the emotionally relevant, in a ‘non-valid’ trial the neutral picture. The participants are instructed to indicate whether the probe appeared on the left or the right side of the screen by pressing a response button as fast as they can. The underlying assumption of the task is that the response time depends on the attention-drawing properties of the stimulus. More specifically, the participants should detect a probe faster when it appears in the location of a picture they are attending at the time of the probe onset. This should be the case for stimuli drawing attention, e.g., threatening stimuli in anxiety-disordered patients. In contrast, one should detect a probe more slowly when it replaces a picture in an unattended visual field, because an additional amount of time is needed to shift attention towards the location of the probe.

The dot-probe task has been used to study attentional reactions in anxiety disordered patients (for a review, see Cisler, Bacon, & Williams, 2009; Cisler & Koster, 2010), who respond faster towards probes that replace threatening stimuli (relative to probes that replace neutral stimuli). This result has been interpreted to reflect the reflexive attentional bias to threatening information in anxious individuals. The dot-probe task has also been employed in experiments with spider-phobic patients (e.g., Mogg & Bradley, 2006; Vrijens, Fleurkens, Nieuwboer, & Rinck, 2009). These studies consistently showed that spider fearful individuals display an attentional bias towards briefly presented pictures of spiders. Reese, McNally, Najmi, and Amir (2010) used a dot probe paradigm with photographs of spiders and cows to facilitate an attentional bias away from threatening material in spider phobics. Patients received a training consisting of a dot-probe identification task in which the dot always replaced the neutral (cow) stimulus. Training reduced the attentional bias for spiders, but only temporarily. Presentation time seems to be of relevance for the attentional bias to disorder-relevant material. Behavioral studies found attentional biases only in response to short presentation times (e.g., Koster et al., 2005). Moreover, there are eye-tracking studies that showed a vigilance–avoidance pattern of eye movements in spider-phobic individuals (Hermans, Vansteenweghen, & Eelen, 1999; Pfugshaupt et al., 2005; Rinck & Becker, 2006; Rinck, Reinecke, Ellwart, Heuer, & Becker, 2005). In these studies eye movements elicited by pictures of spiders in spider phobics consisted of a short fixation followed by the deployment of attention away from the phobic stimulus. Therefore, the bias was only predicted for short, but not for long presentation times. Additionally, we expected enhanced amplitudes of late ERPs (P300, LPP) when the target replaced a spider reflecting facilitated processing and an attentional bias to disorder-relevant material. Behavioral studies found attentional biases only in response to short presentation times (e.g., Koster et al., 2005). Moreover, there are eye-tracking studies that showed a vigilance–avoidance pattern of eye movements in spider-phobic individuals (Hermans, Vansteenweghen, & Eelen, 1999; Pfugshaupt et al., 2005; Rinck & Becker, 2006; Rinck, Reinecke, Ellwart, Heuer, & Becker, 2005). In these studies eye movements elicited by pictures of spiders in spider phobics consisted of a short fixation followed by the deployment of attention away from the phobic stimulus. Therefore, the bias was only predicted for short, but not for long presentation times. Additionally, we expected enhanced amplitudes of late ERPs (P300, LPP) when the target replaced a spider reflecting persistent motivated attention to the phobic stimulus. We again predicted this only for short presentation times. An attentional bias was also expected to be present in response to overall disgusting stimuli, however to a lesser extent.

2. Materials and method

2.1. Participants

Twenty right-handed, non-medicated female patients suffering from spider phobia according to DSM-5 (American Psychiatric Association, 2013) and 20 right-handed non-phobic controls, matched with respect to age and education participated in this study. They were recruited via announcements at the campus and the internet. Diagnoses were made by a board-certified clinical psychologist. The patient group did not differ from controls with respect to age (phobics: M = 23.7 (3.9) years; controls: M (SD) = 21.9 (3.0) years; t(38) = 0.7, p = .500) and years of education (p > .389). All participants gave written informed consent after the nature of the study had been explained to them. The study had been approved by the ethics committee of the University of Graz.

2.2. Procedure

At first, participants completed an online screening consisting of different questionnaires. Participants filled out the Spider Phobia...
Questionnaire (SPQ; Klorman, Weerts, Hastings, Melamed, & Lang, 1974), a scale consisting of 31 items which have to be judged as ‘true’ or ‘false’. The SPQ belongs to the most widely used measures for the extent of spider phobia. Internal consistencies (Kuder–Richardson Formula 20) is reported to be 0.89 for females (Klorman et al., 1974). Moreover, participants filled out the Questionnaire for the Assessment of Disgust Proneness (QADP: Schienle, Walter, Stark, & Vaitl, 2002), which consists of five subscales (death/deformation, body secretions, spoilage/decay, poor hygiene and oral rejection). The internal consistencies of the subscales range between a Cronbach’s α of .69 to .85. The Cronbach’s α of the total scale is 0.90 (Schienle et al., 2002). In addition, participants answered the Scale for the Assessment of Disgust Sensitivity (SADS; Schienle, Dietmaier, Leutgeb, & Ille, 2010). The personality trait disgust sensitivity refers to the tendency of a person to perceive disgust experiences as aversive and uncontrollable. The scale consists of seven items with good internal consistency (Cronbach’s α = 0.85). Finally, participants completed the trait scale of the State-Trait-Anxiety-Inventory (STAI-T; Laux, Glanzmann, Schaffner, & Spielberger, 1981). This questionnaire is widely used to measure trait anxiety. The scale consists of 20 items, which have to be judged on 4-point scales (0 = “hardly ever”; 4 = “nearly ever”). The Cronbach’s alpha was reported to be 0.90 (Laux et al., 1981).

Then the participants underwent a full diagnostic session consisting of a clinical interview (Mini-DIPS, Margraf, 1994). Patients who suffered from any other mental disorder than spider phobia were excluded. Control group participants who suffered from any other mental disorder than spider phobia were excluded. Control group participants who suffered from any other mental disorder than spider phobia were excluded. Additionally, a self-constructed interview on diagnostic criteria of spider phobia according to DSM-5 was conducted.

In a subsequent electroencephalographic (EEG) session participants were presented with a dot probe paradigm (for an overview, see Fig. 1). First, they were shown a cue (a picture pair), and afterwards had to indicate the location of a shortly presented visual stimulus (a dot). Throughout each trial a fixation cross was shown. As the main goal was to measure the correlates of covert attentional shifts without provoking overt eye movements, participants were instructed to keep looking at the fixation cross throughout the experiment. Each trial started with the presentation of the fixation cross alone for 500 ms. The subsequent cue was presented either for 100 ms (short trial) or for 1500 ms (long trial). The cue consisted of picture pairs, of which one was affectively salient (a spider or a disgusting object) and the other was neutral. Thus we presented the following combinations: 16 Spider–Neutral, 16 Disgust–Neutral, 16 Neutral–Neutral picture pairs (for examples, see Fig. 1). Picture repetition rates were held constant for the three categories. All spider pictures are taken from our own picture set (Schienle, Schäfer, Walter, Stark, & Vaitl, 2005) and showed spiders in different environments. All disgust pictures were taken from our own picture set (Schienle, Stark, & Vaitl, 2001; Schienle et al., 2005) and showed the domains ‘poor hygiene’, ‘spoiled food’, and ‘repulsive animals’ (e.g., worms, snails). Neutral pictures were taken partly from the International Affective Picture System (IAPS, Lang, Bradley, & Cuthbert, 1999) and partly from our own picture set (Leutgeb, Schöngaßner, & Schienle, 2014), and consisted of household articles or scenes. The three categories were roughly matched with respect to color, brightness, and the complexity of its content. A rater classified pictures according to color and brightness, and pictures were matched based on this classification. Complexity of content was judged based on the number of objects (e.g., a picture of a single spider was matched with a picture of a single tea cup) and with respect to picture background (e.g., a picture of a spider on a lawn was matched with a picture of a watering can standing on a lawn). The matching was confirmed by a second rater. To control for effects of laterality, half of the time affectively salient pictures were shown on the left or right side of the screen (and neutral pictures on the right side). All pictures were 17.4 cm high and 13.1 cm wide. The cue was followed by a blank (variable presentation time: 100–300 ms in steps of 100 ms) where again only the fixation cross was shown. The variable delay between the picture pair and the dot probe was employed to cancel out mid-latency potentials occurring time-locked to the preceding cue. The subsequent dot-probe consisted of a white dot (14 mm diameter) on a black screen which appeared at the location of one of the pictures (either affectively salient or neutral) for 150 ms. The visual angle between the fixation cross and the center of the dot was 5.5°. There were two validities: in 50% of trials the dot appeared on the side of the spider or disgust picture (valid), whereas in 50% of trials the dot appeared on the side of the neutral picture (non-valid). The location of the dot varied randomly from trial to trial. Participants were instructed to decide whether the dot was located on the left or the right half of the screen and to respond with a button press of their dominant right hand (2 buttons; one for left and one for right). Participants were told that their main task was to accurately judge the location of the dot. The maximum response time allowed was 1000 ms. The whole experiment consisted of 320 trials (32 picture pairs for each of

![Fig. 1. Overview of the paradigm of the current study and examples for presented pictures.](image-url)
the two emotionally relevant categories (Spider–Neutral, Disgust–Neutral), the two validities and the two presentation times, plus 32 Neutral–Neutral pairs for each of the two presentation times). The experiment had a duration of about 12 min.

2.3. Acquisition and analyses of behavioral data and EEG

Attentional bias indices were calculated by subtracting response times to valid trials from response times to invalid trials. A positive index reflects orienting towards threat, whereas a negative index reflects avoidance of threat (Bradley, Mogg, Falla, & Hamilton, 1998).

The EEG was recorded with a Brain Amp 32 system (Brain Products GmbH, Gilching). Data were sampled with 2500 Hz and passband was set to 0.016–70 Hz. We employed an Easy-Cap electrode system (Falk Minow Services, Munich) and recorded the EEG from 29 sites (T1, T2, F3, F4, F7, F8, C1, C2, F5, F6, C3, C4, T7, T8, C1, C2, C5, C6, P3, P4, P7, P8, O1, O2, Fz, Cz, Pz) including the mastoids (T9, T10). All sites were referenced to FCz. A bipolar horizontal electrooculogram (EOG) was recorded from the epicenter of the left and right eye, and a unipolar vertical EOG was recorded from the infra-orbital position of the right eye. The EEG and the EOG were recorded with Ag/AgCl electrodes. Prior to the placement of the electrodes, the sites on the participants’ scalp and face were cleaned with alcohol and gently abraded. All impedances of the EEG electrodes were below 5 kΩ. For analyses, EEG data were down-sampled to 250 Hz. Afterwards, the EEG was re-referenced to the average of Tp9 and Tp10. A raw data analysis was performed and influential artifacts were excluded via visual inspection. Independent component analysis (ICA) was computed in order to correct for EOG artifacts. EOG relevant ICs were identified by visual inspection and comparison to EOG channels. We analyzed electrocortical reactions of participants to the target: EEG data were segmented into epochs of 900 ms starting 100 ms before the onset of the dot probe. Subsequently, segments were semi-automatically inspected to discard remaining artifacts. After artifact correction data were low-pass filtered (30 Hz, 24 dB/octave) and a baseline correction was performed using the first 100 ms as reference. Epochs were averaged separately for each condition. The mean numbers of artifact-free trials were as follows: Phobics: short trials: Spider–Neutral = 27.9, Disgust–Neutral = 28.2, Neutral–Neutral = 28.1; long trials: Spider–Neutral = 28.3, Disgust–Neutral = 27.9, Neutral–Neutral = 27.9; Controls: short trials: Spider–Neutral = 28.9, Disgust–Neutral = 27.7, Neutral–Neutral = 28.2; long trials: Spider–Neutral = 29.3, Disgust–Neutral = 27.5, Neutral–Neutral = 29.1. Magnitudes of the ERP components were extracted via average amplitudes for the time windows 80–180 ms (P100), 340–500 ms (P300), and 550–770 ms (late positive potential, LPP) based on previous work (Brosch et al., 2008; Leutgeb et al., 2009; Pourtois et al., 2004). As the P100 is usually detected at parieto-occipital sites (e.g., Pourtois et al., 2004, 2008, 2011) we analyzed data at O1, O2, P7 and P8. However, no significant interaction effects emerged (all ps > .129). Therefore, we pooled activations at a parietal (P3, P4, Pz), a central (C3, C4, Cz), and a frontal (F3, F4, Fz) cluster.

For statistical data analyses IBM SPSS Statistics 20 (IBM, Armonk) was used. Questionnaire data were submitted separately to between-groups t-tests. Mean response times, response accuracy, and ERP amplitudes (P100, P300, LPP) were submitted separately to 2 × 2 × 2 × 2 ANOVAs with GROUP (Phobics, Controls) as a between subjects factor and TIME (100 ms, 1500 ms), CATEGORY (Spider–Neutral, Disgust–Neutral), and VALIDITY (valid, non-valid), as repeated measurements factors. The attentional bias index was submitted to a 2 × 2 × 2 ANOVA with GROUP (Phobics, Controls) as a between subjects factor and TIME (100 ms, 1500 ms), and CATEGORY (Spider–Neutral, Disgust–Neutral) as repeated measurements factors. For the ANOVAs the assumption of sphericity was never violated. We report η² as effect sizes according to Levine and Hullett (2002), as well as Olejnik and Algina (2003). According to Cohen (1988), the values of effect size, .059 > η² > .001, .138 > η² > .059, η² > .138 are indicative of a small, a medium, and a large effect respectively. To clarify significant interactions, further analyses were conducted by means of between and within group t-tests.

3. Results

3.1. Questionnaire data

As expected, patients scored significantly higher than controls in the disorder-specific questionnaire (SPQ; see Table 1). Phobics reported higher disgust proneness according to the QADP, which was due to higher scores on the subscale spoilage/decay and oral rejection, whereas there were no significant group differences for the other subscales. Phobics were more disgust-sensitive than controls as revealed by the SADS. There was no significant group difference in trait anxiety according to the STAI-T.

3.2. Response times, response accuracy, and attentional bias indices

The ANOVA on response times revealed a significant interaction for GROUP x CATEGORY (F(1,38) = 4.7, p = .037, η² = .001), whereas all other interactions were non-significant (all ps > .145). Post-hoc t-tests revealed no significant group differences in response to spider and disgust stimuli (all ps > .118). Post-hoc t-tests within groups revealed faster reactions to spiders than to disgust images within controls (t(19) = 2.9, p = .009, see Table 2), which was not

<table>
<thead>
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<tbody>
<tr>
<td>100 ms Spider–Neutral</td>
<td>Valid</td>
<td>222.3 (65.2)</td>
<td>194.6 (49.8)</td>
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<tr>
<td></td>
<td>Non-valid</td>
<td>223.5 (61.6)</td>
<td>189.9 (49.3)</td>
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<tr>
<td>1500 ms Spider–Neutral</td>
<td>Valid</td>
<td>196.2 (48.6)</td>
<td>177.2 (44.2)</td>
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<td>Non-valid</td>
<td>192.9 (52.6)</td>
<td>172.1 (47.2)</td>
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Table 1

| Questionnaire data and affective responses (means and standard deviations) of phobics and control group participants, as well as significance (p) of between-groups t-tests. QADS = Questionnaire for the Assessment of Disgust Sensitivity; SADS = Scale for Assessing Disgust Sensitivity. SPQ = Spider Phobia Questionnaire; STAI-T = State-Trait Anxiety Inventory, trait version. |
|-----------------|-----------------|--------|----------|
| SPQ             | Controls        | p      |
| 20.6 (3.3)      | 2.6 (1.9)       | <.001  |
| QADS – Sum      | 2.5 (0.4)       | 2.0 (0.4) | = .002  |
| QADS – death/deformation | 1.6 (0.8) | 1.2 (0.9) | = .191  |
| QADS – body secretions | 2.5 (0.5) | 2.4 (0.4) | = .739  |
| QADS – spoilage/decay | 2.7 (0.5) | 1.9 (0.6) | < .001  |
| QADS – hygiene | 2.4 (0.5)          | 2.4 (0.4) | = .939  |
| QADS – oral rejection | 3.1 (0.6) | 2.2 (0.6) | < .001  |
| SADS            | 8.9 (5.8)       | 3.6 (3.4) | = .001  |
| STAI-T          | 38.3 (8.8)      | 38.4 (11.0) | = .962  |

Table 2

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true for phobics ($t(19) = 2.0, p = .052$). The ANOVA revealed a significant main effect for TIME ($F(1,38) = 35.8, p < .001, \eta^2 = .44$), which was a result of faster reactions following trials with a long presentation time relative to trials with a short presentation time ($p < .001$). The other main effects were non-significant (all $p > .066$).

The ANOVA on response accuracy revealed a significant interaction for TIME $\times$ GROUP ($F(1,38) = 5.5, p = .025, \eta^2 = .020$), whereas all other interactions were non-significant (all $p > .280$). Post-hoc $t$-tests revealed a higher accuracy in phobics relative to controls in trials with a long presentation time ($t(26.6) = 3.0, p = .007$; see Table 3), which was not true for short trials ($t(38) = 0.5, p = .609$). Phobics had a higher accuracy in trials with a long presentation time ($t(19) = 2.7, p = .014$) relative to trials with a short presentation time. This was not true for controls ($t(19) = 0.8, p = .453$). The ANOVA revealed no significant main effects (all $p > .183$).

For the attentional bias index there were no significant interactions (all $p > .384$) or main effects (all $p > .080$) (see Table 4).

### 3.3. ERP data

Grand average waveforms (frontal, central, parietal) of phobics and controls in response to targets are displayed in Fig. 2.

#### 3.3.1. P100. (80–180 ms)

For all three clusters the ANOVAs revealed no significant interactions or main effects (frontal: all $p > .224$; central: all $p > .135$; parietal: all $p > .097$).

#### 3.3.2. P300. (340–500 ms)

A topographical map for activation differences in the time frame of the P300 (340–500 ms) is displayed in Fig. 3.

At the frontal cluster the ANOVA revealed a significant interaction for CATEGORY $\times$ VALIDITY ($F(1,38) = 4.4, p = .044, \eta^2 = .067$). Post-hoc $t$-tests across both groups and presentation times revealed that within non-valid trials there were significantly higher amplitudes in response to Disgust–Neutral pairs relative to Spider–Neutral pairs ($p = .014$), which was not true for valid trials. For both categories there were no significant differences between amplitudes in response to valid and non-valid trials (all $p > .180$). All other interactions of the ANOVA remained non-significant (all $p > .066$). Moreover, the ANOVA revealed a significant main effect for TIME ($F(1,38) = 189.2, p < .001, \eta^2 = .444$), which resulted from higher amplitudes in response to short trials relative to long trials. There was a significant main effect for CATEGORY ($F(1,38) = 4.2, p = .048, \eta^2 = .056$), which resulted from higher amplitudes in response toDisgust–Neutral pairs relative to Spider–Neutral pairs. The other main effects remained non-significant (all $p > .770$).

At the central cluster the ANOVA revealed a significant interaction for GROUP $\times$ TIME $\times$ CATEGORY $\times$ VALIDITY ($F(1,38) = 5.0, p = .032, \eta^2 = .028$), whereas all other interactions were non-significant (all $p > .074$). There was a significant main effect of TIME ($F(1,38) = 195.0, p < .001, \eta^2 = .69$), which resulted from higher amplitudes in response to short trials relative to long trials. There was a significant main effect for CATEGORY ($F(1,38) = 6.4, p = .016, \eta^2 = .034$), which was due to higher amplitudes in response to Disgust–Neutral pairs relative to Spider–Neutral pairs. The other main effects of the ANOVA remained non-significant (all $p > .223$).

To clarify the GROUP $\times$ TIME $\times$ CATEGORY $\times$ VALIDITY interaction we removed the factors TIME and GROUP from the ANOVA. Within phobics the ANOVA revealed a significant CATEGORY $\times$ VALIDITY interaction for short trials ($F(1,19) = 9.7, p = .006, \eta^2 = .066$). There was a significant main effect of VALIDITY ($F(1,19) = 4.7, p = .043, \eta^2 = .077$) stemming from higher amplitudes in response to valid relative to non-valid trials, whereas the main effect for CATEGORY remained non-significant ($p = .741$). Post-hoc $t$-tests revealed that there were significantly higher amplitudes in response to valid relative to non-valid trials ($p = .002$) only in response to Spider–Neutral pairs (see Fig. 4), but not in response to Disgust–Neutral pairs ($p = .887$). For long trials there was no significant CATEGORY $\times$ VALIDITY interaction ($p = .883$). There was a significant main effect for CATEGORY ($F(1,19) = 7.1, p = .015, \eta^2 = .014$) stemming from higher amplitudes in response to Disgust–Neutral relative to Spider–Neutral, whereas the main-effect for VALIDITY was non-significant ($p = .609$). Within controls, the ANOVA revealed no significant interaction or main effects for short or long trials (all $p > .123$).

At the parietal cluster the ANOVA revealed significant interactions for GROUP $\times$ TIME $\times$ CATEGORY $\times$ VALIDITY ($F(1,38) = 6.4, p = .016, \eta^2 = .033$) and GROUP $\times$ TIME $\times$ CATEGORY ($F(1,38) = 6.2, p = .018, \eta^2 = .043$), whereas all other interactions remained non-significant (all $p > .283$). There was a significant main effect for GROUP ($F(1,38) = 7.9, p = .008, \eta^2 = .086$), which resulted from higher amplitudes in controls relative to phobics. A significant main effect for TIME ($F(1,38) = 100.8, p < .001, \eta^2 = .297$) was due to higher amplitudes in response to short trials relative to long trials. A significant main effect for CATEGORY ($F(1,38) = 8.1, p = .007, \eta^2 = .037$) resulted from higher amplitudes in response to Disgust–Neutral pairs relative to Spider–Neutral pairs. There was no significant main effect for VALIDITY ($p = .964$).

To clarify the GROUP $\times$ TIME $\times$ CATEGORY $\times$ VALIDITY interaction we removed the factors TIME and GROUP from the ANOVA. Within phobics the ANOVA revealed a significant CATEGORY $\times$ VALIDITY interaction for short trials ($F(1,19) = 5.2, p = .034, \eta^2 = .026$), whereas there were no significant main-effects (all $p > .344$). Post-hoc $t$-tests revealed that there were significantly higher amplitudes in response to valid relative to non-valid trials ($p = .049$) only in response to Spider–Neutral pairs (see Fig. 4), but not in response to Disgust–Neutral pairs ($p = .538$). For long trials there was no significant interaction ($p = .414$). There was a significant main effect for CATEGORY ($F(1,19) = 8.0, p = .011, \eta^2 = .030$) stemming from higher amplitudes in response to

### Table 3

Response accuracy (means and standard deviations) of phobics and control group participants to a dot-probe that was presented valid or non-valid relative to the emotionally relevant picture within a previous picture pair (Spider–Neutral or Disgust–Neutral) with a short (100 ms) or long (1500 ms) presentation time.

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<tr>
<td>100 ms</td>
<td>Spider–Neutral</td>
<td>99.2 (1.4)</td>
<td>99.1 (1.8)</td>
</tr>
<tr>
<td></td>
<td>Non-valid</td>
<td>98.9 (1.8)</td>
<td>98.9 (1.8)</td>
</tr>
<tr>
<td></td>
<td>Disgust–Neutral</td>
<td>98.9 (2.1)</td>
<td>99.4 (2.2)</td>
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<tr>
<td></td>
<td>Non-valid</td>
<td>98.9 (2.1)</td>
<td>99.4 (2.2)</td>
</tr>
<tr>
<td>1500 ms</td>
<td>Spider–Neutral</td>
<td>99.5 (1.5)</td>
<td>98.8 (2.1)</td>
</tr>
<tr>
<td></td>
<td>Non-valid</td>
<td>99.4 (1.3)</td>
<td>98.4 (2.2)</td>
</tr>
<tr>
<td></td>
<td>Disgust–Neutral</td>
<td>100.0 (0.0)</td>
<td>99.4 (1.6)</td>
</tr>
<tr>
<td></td>
<td>Non-valid</td>
<td>99.8 (0.6)</td>
<td>99.2 (1.7)</td>
</tr>
</tbody>
</table>

### Table 4

Attentional bias index (means and standard deviations) of phobics and control group participants.

<table>
<thead>
<tr>
<th>Presentation time</th>
<th>Picture type</th>
<th>Phobics</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 ms</td>
<td>Spider–Neutral</td>
<td>1.2 (19.7)</td>
<td>-4.8 (17.7)</td>
</tr>
<tr>
<td></td>
<td>Disgust–Neutral</td>
<td>5.7 (24.2)</td>
<td>4.2 (19.7)</td>
</tr>
<tr>
<td>1500 ms</td>
<td>Spider–Neutral</td>
<td>-3.4 (25.4)</td>
<td>-5.2 (21.8)</td>
</tr>
<tr>
<td></td>
<td>Disgust–Neutral</td>
<td>-3.7 (20.6)</td>
<td>1.5 (17.1)</td>
</tr>
</tbody>
</table>

For all analyses there were no significant differences between amplitudes in response to valid and non-valid trials (all $p > .180$). All other interactions of the ANOVA remained non-significant (all $p > .066$). Moreover, the ANOVA revealed a significant main effect for TIME ($F(1,38) = 195.0, p < .001, \eta^2 = .69$), which resulted from higher amplitudes in response to short trials relative to long trials. There was a significant main effect for CATEGORY ($F(1,38) = 6.4, p = .016, \eta^2 = .034$), which resulted from higher amplitudes in response to Disgust–Neutral pairs relative to Spider–Neutral pairs. The other main effects remained non-significant (all $p > .770$).
Disgust–Neutral relative to Spider–Neutral, whereas the main-effect for VALIDITY was non-significant ($F_{(1,19)} = 0.1, p = .992, \eta^2 = .001$). Within controls, the ANOVA for short trials revealed no significant interaction ($F_{(1,19)} = .657$). A significant main-effect for CATEGORY ($F_{(1,19)} = 5.0, p = .038, \eta^2 = .034$) stemmed from higher amplitudes in response to Disgust–Neutral relative to Spider–Neutral. Within controls, the ANOVA for long trials revealed no significant interaction or main effects (all $p$s > .136).

### 3.3.3. LPP (550–770 ms)

At the frontal and central cluster the ANOVAs revealed no significant interactions (frontal: all $p$s > .188; central: all $p$s > .103). However, there were significant main effects for TIME (frontal: $F_{(1,38)} = 148.0, p < .001, \eta^2 = .353$; central: $F_{(1,38)} = 168.6, p < .001, \eta^2 = .411$), which resulted from higher amplitudes in response to short relative to long trials. Significant main effects for CATEGORY (frontal: $F_{(1,38)} = 11.3, p = .002, \eta^2 = .005$; central: $F_{(1,38)} = 13.3, p = .001, \eta^2 = .005$) resulted from significantly higher amplitudes in response to Disgust–Neutral pairs relative to Spider–Neutral pairs. The other main effects remained non-significant (frontal: all $p$s > .473; central: all $p$s > .302).

At the parietal cluster the ANOVA revealed a significant interaction for GROUP $\times$ CATEGORY $\times$ VALIDITY ($F_{(1,38)} = 4.2, p = .047, \eta^2 = .002$), whereas all other interactions remained non-significant.

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**Fig. 2.** Grand average waveforms (frontal, central, parietal) of phobics and controls in response to the target (dot). After the offset of a previously presented picture pair (Spider–Neutral, presented for 100 ms) the dot was presented either on the side of the spider picture (valid), or on the side of the neutral picture (non-valid).
A significant main effect for TIME ($F(1,38) = 96.4, p < .001, \eta^2 = .326$) was due to higher amplitudes in response to short trials relative to long trials. A significant main effect for CATEGORY ($F(1,38) = 7.74, p = .008, \eta^2 = .006$) resulted from higher amplitudes in response to Disgust–Neutral pairs relative to Spider–Neutral pairs. There were no significant main effects for GROUP or VALIDITY (all ps > .055).

To clarify the GROUP × CATEGORY × VALIDITY interaction we removed the factors TIME and GROUP from the ANOVA. Within phobics the ANOVA revealed no significant CATEGORY × VALIDITY interactions or main-effects for both trial durations (all ps > .050). Within controls, the ANOVA for short trials revealed no significant interaction (p = .768). A significant main-effect for CATEGORY ($F(1,19) = 14.6, p = .001, \eta^2 = .030$) stemmed from higher amplitudes in response to Disgust–Neutral relative to Spider–Neutral.

Within controls, the ANOVA for long trials revealed no significant interaction or main effects (all ps > .142).

3.3.4. Summary

The main result was higher centro-parietal amplitudes of the P300 in response to valid relative to invalid trials. This was only true for phobics, for short trials and in response to Spider–Neutral picture pairs. Thus, the modulation could not be found in controls, in response to long trials, or in response to Disgust–Neutral picture pairs.

4. Discussion

This study investigated electrocortical correlates of attention and avoidance in spider phobia via a dot probe task. We found
could also reflect reduced attention to the target in general. lower amplitudes of P300 and LPP in phobics relative to controls either at short or at long presentation times. However, the overall amplitudes at parieto-occipital regions, possibly reflecting facilitated attention to the feared object in specific phobia. The current investigation suggests that there is also sustained attention to the phobic object if disorder-relevant pictures and neutral pictures are presented simultaneously and that motivated attention persists in the time window of the P300 could not be shown for later slow wave components (i.e., the LPP from 550–770 ms). It has to be noted that, at least according to their ERPs, controls also showed attentional capture effects, but independent of cue validity, suggesting that they did not show any attentional selection between unpleasant and neutral stimuli, either at short or at long presentation times. However, the overall lower amplitudes of P300 and LPP in phobics relative to controls could also reflect reduced attention to the target in general.

The reported enhancement of P300 amplitudes might be a very sensitive correlate of the initial attentional capture by the phobic stimulus which has been found by eye-tracking studies (Hermans et al., 1999; Pfflugshaupt et al., 2005; Rinck & Becker, 2006; Rinck et al., 2005). Thus, even if phobics are left with the choice to direct their attention to a neutral picture, vigilance towards the phobic stimulus seems to persist throughout the time window of the P300. The results might also be interpreted to reflect difficulty in disengaging attention from the phobic stimulus, as P300 amplitudes were enhanced in response to invalid trials. However, as a limitation of the current study it has to be noted that our analyses on behavioral data (i.e., attentional bias indices) did not reveal significant results explaining the validity-specific differentiation of ERPs. A possible explanation concerns the mean response times which were faster than the latency of the P300. Thus, it seems that an attentional bias was not evident up to 340 ms after the probe. In other words, it might be that ERPs were able to assess processing stages developing after (and independently of) the behavioral response. In line with this, other studies have been published that were unable to detect an attentional bias in behavioral data but found an effect in electrocortical correlates (e.g., Sun et al., 2012). However, there might be another explanation for the lack of effect in behavioral data: in accordance with other studies employing a dot probe paradigm (e.g., Brosch et al., 2008, 2011; Pourtois et al., 2004) we employed a variable blank between cue and probe to cancel out mid-latency potentials occurring time-locked to the preceding cue. Thus, it should be noted, that stimulus onset asynchrony has been reported to have an impact on response times (Posner, Rafal, Cholea, & Vaughan, 1985).

As mentioned above, and in contrast to our predictions, there were no differential effects of validity in earlier ERP time windows. Previous studies showed validity-specific variation of P100 amplitudes at parieto-occipital regions, possibly reflecting facilitated processing of threat-relevant information (e.g., Brosch et al., 2008, 2011; Mueller et al., 2009; Pourtois et al., 2004; Rossignol et al., 2013). However, it has to be taken into account, that the presented materials are not directly comparable. Earlier experiments employed emotional and neutral facial expressions as cueing stimuli, whereas we presented our participants with spiders in natural environments and neutral scenes. The only published study employing a modified dot probe task with scenes (Sun et al., 2012) also found no differential validity effect on P100 amplitudes. However, as a limitation of the current study it also has to be noted that concerning the picture material, animate objects (i.e., spiders) were compared with inanimate objects (e.g., household articles). It is possible, that this had an effect on the P100 that has been found to be sensitive to animacy (e.g., Baylas & Koldewyn, 2013). Moreover, there is evidence that the P300 as an indicator of semantic integration and cognitive updating could be affected by animacy (Proverbio, Del Zotto, & Zani, 2007). The lack of significant results in the time window of the P100 could also be explained by differential effects in the two visual hemi-fields or in response to different inter-stimulus-interval durations. As already mentioned, those parameters were counterbalanced, but not included as factors in the current analyses.

As expected, we only detected statistically significant effects on target-related ERPs when the presentation time of the cue was short (i.e., 100 ms), but not when it was long (i.e., 1500 ms). According to response times, reactions were longer in response to short presentations relative to long presentations. This might be an indicator that short presentations draw more attention and therefore limit resources for task processing. Our ERP data also support this idea: independent of validity, P300 amplitudes were higher in response to targets following short relative to long presentations. According to the vigilance–avoidance hypothesis gaze deployment (reflecting avoidance) start after approximately 1 s (e.g., see Rinck & Becker, 2006). Therefore, it might be that long presentation durations triggered avoidance behavior resulting in reduced motivated attention and amplitude attenuation. However, as we did not record eye movements this interpretation is speculative.

5. Conclusion

Earlier studies employing passive viewing paradigms and presenting participants with single pictures observed motivated attention to the feared object in specific phobia. The current investigation suggests that there is also sustained attention to the phobic object if disorder-relevant pictures and neutral pictures are presented simultaneously and that motivated attention persists after the offset of the phobic stimulus.

References


