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Habituation of self-reported anxiety and cortical hyper-vigilance during image-based exposure to spiders

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ABSTRACT

Background and objectives: The aim of the study was to examine habituation of subjective anxiety and electrophysiological correlates of cortical hyper-vigilance during exposure to spider images among high ($n = 12$) and low ($n = 11$) spider fear groups.
Methods: Participants viewed a six-stage hierarchy of spider images. The images used at stage 1 and stage 6 were the same. Subjective anxiety was rated at four intervals during each three-minute exposure stage (0, 60, 120, and 180 s) and event-related potentials (ERPs) were averaged across these epochs (0–60, 60–120, 120–180).
Results: High spider fearfuls demonstrated greater habituation of self-reported anxiety within and between exposure stages compared to low fearfuls. Consistent with attentional hyper-vigilance, the high-fear group also demonstrated greater P1 amplitude in response to spider images. In both groups, habituation of P1 amplitude was found at later relative to earlier stages, but increased at stage six when the stage 1 image was re-presented, despite low subjective anxiety.
Limitations: While the passive viewing paradigm mirrored image-based exposure, it was not possible to determine whether participants engaged in avoidance strategies. In addition, further research is needed to assess the relevance of habituation and reinstatement of P1 amplitude to therapeutic outcome.
Conclusions: Habituation of subjective anxiety during image-based exposure is not necessarily accompanied by a reduction in measures of cortical hyper-vigilance. The reinstatement of the P1 response may indicate either re-activation of previous associations, less avoidance, or a more generalised dishabituation mechanism.

1. Introduction

Graded exposure treatment involves progression through a hierarchy of exposure stages (from least to most anxiety-provoking) until a reduction in anxiety is observed, a process known as habituation (Choy, Fyer, & Lipsitz, 2002; Öst, 1989). While *in vivo* exposure is the gold standard for phobia treatment (Choy et al., 2002), exposure-based treatments may also be imaginal, virtual, or vicarious in nature. For example, exposure to images is effective in the treatment of specific phobia and can be delivered in the online environment (Bornas, Tortella-Feliu, Llabrés, & Fullana, 2001; Matthews, Naran, & Kirkby, 2015; Matthews, Scanlan, & Kirkby, 2012; Müller, Kull, Wilhelm, & Michael, 2011). Given that many do not seek treatment for specific phobia (Andrews, Henderson, & Hall, 2001; Lépine, 2002), online exposure treatments have potential to overcome barriers such as the time, cost and accessibility of traditional face-to-face treatments (Bebbington et al., 2000; Stinson et al., 2007). Exposure to images also allows exploration of the mechanisms underlying exposure treatment, including the electrophysiological processes involved in the activation and habituation of fear. While the P1 component of the ERP waveform has been suggested as a cortical mechanism related to attentional hyper-vigilance in specific fear and other anxiety disorders (O'Toole & Dennis, 2012), to our knowledge there is little research examining the habituation of the P1 component during exposure to fear-related images.

According to Emotional Processing Theory (EPT), activation of the fear response (self-report or physiological) followed by a

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reduction in anxiety (both within and between exposure trials) is necessary for corrective learning to occur, such that existing stimulus-response associations are replaced or inhibited by new associations that are incompatible with the fear response (Foa & Kozak, 1986; Foa, Huppert, & Cahill, 2006). While there is mixed evidence with regard to the relationship between habituation and therapeutic outcome (Craske et al., 2008), generalisation of habituation across multiple different images (an analogue to between stage habituation) has been associated with less behavioural avoidance of spiders in image-based exposure (Matthews et al., 2015). According to inhibitory learning perspectives, simultaneous activation of new associations and the suppression of old associations is necessary for long-term treatment benefits, and factors such as context, time, and optimal attentional focus are important moderators of treatment outcome (Bouton, 1993; Craske et al., 2008; Myers & Davis, 2007). Consistent with this view, return of fear can be contextually driven, and is greater when assessed in a different context to exposure (Mystkowski, Craske, Echiverri, & Labus, 2006). Thus, demonstrating extinction learning to multiple different contexts (or images) is likely to be important.

While inhibitory learning perspectives focus on extinction processes (reductions in the strength of learned responses) and EPT focuses on corrective learning through habituation (or a reduction in strength of unlearned responses), both perspectives highlight the importance of attentional focus in exposure therapy. Attentional focus is considered important for noticing and processing non-threatening information about the stimulus in order to either eliminate maladaptive stimulus-response associations (as suggested in EPT), or to develop new non-fearful learned associations (as suggested in inhibitory learning perspectives) (Podina, Koster, Philippot, Dethier, & David, 2013). However, automatic attentional bias toward threat-related stimuli is also cited as a potential factor in the onset and maintenance of anxiety disorders such as specific phobia (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Cisler & Koster, 2010; Mogg & Bradley, 2006; Van Bockstaele et al., 2014). There are three specific components of attentional bias: enhanced attentional capture, difficulty disengaging attention, and attentional avoidance of threat-related stimuli (Cisler & Koster, 2010). Each component may be activated according to a different time-course and to a differing extent depending on the experimental task and the anxiety disorder in question (Cisler, Bacon, & Williams, 2009; Weierich, Treat, & Hollingworth, 2008). In specific fear, there is evidence for enhanced attentional capture of fear-relevant stimuli across a number of experimental paradigms (Bar-Haim et al., 2007; Cisler & Koster, 2010; Cisler et al., 2009; Mogg & Bradley, 2006), a phenomenon known as attentional hyper-vigilance (Pflugshaupt et al., 2005). Automatic capture of attention may also be followed by difficulty disengaging attention from fear-relevant stimuli (Gerdes, Pauli, & Alpers, 2009), or a vigilant-avoidant pattern in which automatic capture is followed by abrupt attentional dis-engagement which may act to facilitate escape or avoidance (Mogg & Bradley, 2006; Pflugshaupt et al., 2005; Öhman & Mineka, 2001).

Attentional hyper-vigilance towards fear-relevant stimuli is thought to be mediated by a direct thalamic-amygdala pathway which acts to enhance attentional capture via projections to the visual cortex (Garrido, Barnes, Sahani, & Dolan, 2012). In specific phobia, amygdala activation is enhanced during subliminal exposure to images of spiders (Ipser, Singh, & Stein, 2013) and when attention is directed towards phobic relative to neutral stimuli within the same array (Alpers & Gerdes, 2009). The amygdala also plays an important role in the acquisition, storage and expression of fear-related memories, including the automatic activation of conditioned fear responses (LeDoux, 2000; Öhman & Mineka, 2001), and modulation of the emotional content of explicit memories (LeDoux, 2000).

It has been theorised that the balance of automatic (bottom-up) and goal-directed (top-down) attentional mechanisms is disrupted in anxiety disorders. According to Attentional control theory, anxiety is associated with increased influence of the automatic attentional system involving the temporo-parietal and ventral-frontal cortices, and reduced influence of a goal-directed attentional system centred in the prefrontal cortex (Eysenck, Derakshan, Santos, & Calvo, 2007). Similarly, Bishop (2007) suggests that threat-related attentional biases occur due to an amplified threat signal from the amygdala, and a reduced control signal from the prefrontal cortex. Both of these structures have re-entrant connections to the visual cortex and may modulate visual processing via these connections (Bishop, 2007). The extinction of learned fear is also mediated by the prefrontal cortex (PFC) through its interaction with structures such as the amygdala and hippocampus (McNally, 2007; Sotres-Bayon, Cain, & LeDoux, 2006). Thus, the medial PFC may act to inhibit the activity of the amygdala in order to regulate the expression of fear.

While brain-imaging research provides insight into the brain areas associated with phobic symptoms, event-related potentials (ERPs) allow examination of the time course of cognitive processes with millisecond resolution. The P1 ERP component is a positive inflection occurring approximately 100–200ms post-stimulus which reflects processing within early extra-striate visual pathways (Clark & Hillyard, 1996; Mangun, 1995). P1 amplitude is modulated by attention (Clark & Hillyard, 1996; Mangun, 1995) and by stimulus valence, particularly for negative stimuli (Olofsson, Nordin, Sequeira, & Polich, 2008). Unlike later ERP components such as the LPP and P300, in which enhancement may reflect emotional significance and broader attentional allocation (Leutgeb, Schafer, & Schienle, 2009), the P1 component is argued to reflect automatic capture of attention (cortical hyper-vigilance) and may be influenced by activation of the amygdala (Olofsson et al., 2008).

Several studies have demonstrated that people with anxiety disorders such as specific phobia show enhanced P1 amplitude relative to controls (Kolassa, Musial, Kolassa, & Miltner, 2006; Michalowski et al., 2009). For example Kolassa et al. (2006) reported enhanced P1 amplitude to spider stimuli among both spider and social phobics compared to a non-phobic group, suggesting generalised as opposed to fear-specific hyper-vigilance. Similarly, Michalowski et al. (2009) found that spider and non-spider phobics demonstrated higher P1 amplitude to all images (pleasant, unpleasant, neutral) relative to non-phobics during a passive viewing task, again suggesting non-specific attentional hyper-vigilance.

While previous research has demonstrated habituation of self-report and physiological measures of anxiety during computer-delivered exposure to images (Bornas et al., 2001; Matthews et al., 2012, 2015; Müller et al., 2011), it is not clear whether exposure to images results in habituation of cortical hyper-vigilance as indexed by the P1 component. Leutgeb et al. (2009) examined later P300 and LPP amplitudes in response to cognitive behavioural therapy (CBT) including exposure among spider phobics. Following treatment, the treatment group showed reduced symptom severity and rated pictures of spiders as less negative than before the treatment. However, contrary to predictions, there were no reductions in P300 or early LPP amplitude in response to spider images at post-treatment. Thus, it was argued that CBT did not impact attentional hyper-vigilance. In contrast, an increase in late LPP amplitude suggested more elaborate processing of emotional stimuli following treatment. However, this study did not specifically examine early attentional allocation as indexed by the P1 component.

Although no previous study has examined the effects of exposure to fear-relevant images on ERP indices of early selective

attention in anxious participants, Olofsson and Polich (2007) investigated the effects of stimulus repetition on P1 amplitude in participants without a specified anxiety disorder when viewing unpleasant, pleasant and neutral images. Unexpectedly, they found that P1 amplitude increased significantly over repetitions for neutral stimuli but decreased for unpleasant stimuli. This suggests that early attentional processes are sensitive to repeated exposure. O'Toole and Dennis (2012) examined the effects of training attention away from threat (attention bias modification) in non-anxious participants who showed a pre-training bias toward threat, using images of angry (threatening) and happy (non-threatening) faces. They found that both P1 amplitude and subjective anxiety decreased in response to all faces after training, suggesting that the training reduced automatic capture of attention to face cues, even non-threatening ones. This was interpreted to reflect the effects of habituation. However, P1 amplitude was only examined pre and post training and the effects of exposure during trials were not investigated.

Given that no previous research has measured habituation of the P1 component during graded exposure to fear-relevant images, the present study aimed to examine self-reported anxiety and cortical hyper-vigilance among high and low spider fearful participants during a passive viewing paradigm similar to that used in image-based exposure interventions (Matthews, Scanlan, & Kirkby, 2010; Matthews, Wong, Scanlan, & Kirkby, 2011; Matthews et al., 2012, 2015). It was hypothesised that spider fearful participants would experience greater self-reported anxiety and greater P1 amplitude compared to non-spider fearful participants in response to spider images. In addition, it was hypothesised that the high but not the low spider fear group would demonstrate habituation of self-reported anxiety within and across each stage of the program. If exposure to fear-relevant images results in habituation of attentional hyper-vigilance, it was hypothesised that P1 amplitude would also show a reduction within and between successive exposure stages among high-fear but not low-fear participants.

2. Method

2.1. Participants

Twenty six female first year psychology students were recruited from the University of Tasmania and received course credit for participation. Participants were screened using the Spider Phobia Questionnaire (SPQ) (Watts & Sharrock, 1984) and selected on the basis of high (>17) or low (<9) scores (Kopp & Altman, 2005). All participants completed a demographic and medical survey distributed via email. Participants were excluded from the study if they were pregnant or if they reported current or previous psychological and/or neurological disorder, previous treatment for spider phobia, heart conditions, skin allergies and tobacco and illicit drug use. All participants had normal or corrected to normal vision.

Data for three participants were excluded; one high-fear participant chose to discontinue, and one participant from each group was excluded due to excessive artifact in EEG recordings. The final sample consisted of 23 participants (12 high-fear, 11 low-fear) with ages ranging from 18 to 34 years. There was no significant difference between the mean age of high-fear (M = 20.6 years, SD = 4.4) and low-fear (M = 23.5 years, SD = 6.4) groups, $t(21) = -1.26$, $p = 0.22$. Participation was voluntary, all participants gave informed consent, and the study was approved by the University of Tasmania Human Research Ethics Committee.

2.2. Materials

2.2.1. Spider Phobia Questionnaire (SPQ) (Watts & Sharrock, 1984)

The SPQ is a 43-item questionnaire, measuring spider fear across three sub-scales including behavioural reactions, (avoidance and coping), cognitions (vigilance and internal preoccupation) and factual knowledge of spiders. A 33-item version (excluding the 10-item knowledge scale) was used. Items (e.g., do you check the bedroom for spiders before going to bed?) were rated 'yes' or 'no'. The SPQ is can discriminate between phobics and non-phobics and has good internal consistency (Cronbach's alpha = 0.83-0.90; Klorman, Weerts, Hastings, Melamed, & Lang, 1974; Watts & Sharrock, 1984).

2.2.2. Fear of spiders questionnaire (FSQ) (Szymanski & O'Donohue, 1995)

The FSQ is a two factor questionnaire that measures avoidance/help seeking behaviours as well as fear of harm in relation to spiders. It is comprised of 18 items (e.g., I would feel very nervous if I saw a spider now) with responses rated on a seven-point scale ranging from '1' (definitely not) to '7' (absolutely). The FSQ has good split half reliability (0.89), internal consistency (Cronbach's alpha = 0.92–0.97) and re-test reliability (r = 0.91) (Muris & Merckelbach, 1996; Szymanski & O'Donohue, 1995).

2.2.3. Subjective units of distress scale (SUDS) (Hope & Heimberg, 1993)

The SUDS is commonly used to measure self-reported anxiety during exposure treatment and is comprised of a Likert-type scale ranging from '0' (no anxiety) to '100' (extreme anxiety).

2.2.4. Exposure hierarchy

The five images of huntsman spiders were the same as those used in previous research examining self-reported anxiety during online exposure, and were selected based on mean ratings of scariness as judged by spider fearful individuals (see Matthews et al., 2010). A five-stage hierarchy was constructed such that pictures were displayed from least to most scary across successive stages. Stage six consisted of the same image used at Stage one.

2.2.5. EEG recording

Images were presented on a laptop using NeuroScan Stim2 software. EEG data was recorded using a portable NuAmps system with NeuroScan 4.3 software. EEG activity was recorded from 32 sites according to the 10–20 system of electrode placement using a Quickcap with sintered Ag/AgCl electrodes. Impedances were maintained at 10 kΩ or less and data were sampled continuously at a rate of 1000 Hz. A horizontal electroculogram (EOG) was recorded bipolarly from electrodes at the outer canthi of both eyes, and vertical EOG was recorded from electrodes above and below the left eye.

All data was subject to visual inspection, filtered (0.05–30 Hz, 24 dB/Oct) and corrected for ocular artifacts using regression and artifact averaging in NeuroScan Software. Continuous files were epoched from −100ms to 900 ms post-stimulus, baseline corrected at the pre-stimulus interval, with further artifacts rejected with ±100 μV cutoffs. Stimuli were averaged separately across three epochs (0–60, 60–120, 120–180 s) within each three-minute stage.

2.3. Procedure

Eligible participants were invited to attend a two-hour experimental session. All participants gave written informed consent prior to participation. After completing the FSQ, participants were set up for EEG recording. During the experimental task, participants

rated their baseline level of anxiety prior to viewing the first image (Stage 1). Each image was presented for 2 s with an inter-stimulus interval of 1.5 s. There were 90 trials per stage equating to 180 s (or three minutes) of exposure per stage. After each minute of exposure, participants gave SUDS ratings, resulting in ratings at four time points (0, 60, 120, and 180 s) for each of the six exposure stages. Short breaks were taken between each stage and participants were instructed to avoid making overt head and body movements during the experimental tasks.

2.4. Design and data analysis

Raw data were collated and analysed using PASW Statistics 19.0. Significance levels were maintained at 0.05 and Greenhouse-Geisser corrections were applied to repeated measures analyses where appropriate. Significant interactions were followed by analysis of simple main effects with Bonferroni adjustments to correct for inflation of Type I errors.

Univariate ANOVAS were performed to compare high and low-fear groups on baseline measures (age, and FSQ and SPQ scores). Factorial ANOVA was used to measure differences in mean SUDS ratings using a 2(Group: high-fear, low-fear) x 6(Exposure stage: 1, 2, 3, 4, 5, 6) x 4(Time point: 0, 60, 120, 180) mixed factorial design. Peak P1 amplitude and latency at occipital sites were analysed using a 2(Group: High-fear, low-fear) x 6(Stage: 1, 2, 3, 4, 5, 6) x 3(Epoch: 0–60, 60–120, 120–180) x 3 (Site: O1, Oz, O2) mixed factorial repeated measures ANOVA.

3. Results

3.1. Baseline measures

Mean SPQ scores were significantly greater for the high-fear ($M = 22.2$, $SD = 3.4$, range 18–28) relative to the low-fear group ($M = 3.27$, $SD = 1.0$, range 1–4), $F(1,21) = 161.05$, $p < 0.001$. Similarly, mean FSQ scores were significantly greater for the high-fear ($M = 102.0$, $SD = 10.8$, range 84–116) compared to the low-fear ($M = 22.7$, $SD = 6.0$, range 18–37) group, $F(1,21) = 461.20$, $p < 0.001$.

3.2. Anxiety ratings (SUDS)

The main effect of Group was significant, $F(1, 21) = 27.87$, $p < 0.001$ ($\eta_p^2 = 0.57$), with higher SUDS scores for the high-fear ($M = 24.98$, $SD = 10.43$) compared with the low-fear group ($M = 1.74$, $SD = 10.55$). There was a significant main effect of Stage, $F(5,60) = 10.61$, $p < 0.001$ ($\eta_p^2 = 0.34$). The mean SUDS scores for each of the six stages (with standard deviations in parentheses) were respectively 16.5 (14.96), 15.31 (12.57), 12.91 (9.11), 13.71 (12.80), 15.14 (12.8) and 6.60 (7.19). Bonferroni adjusted pair-wise comparisons revealed significant differences between Stages 1, 2, 3, 4, 5, and Stage 6 ($p < 0.008$, Bonferroni corrected), such that anxiety was significantly lower at Stage 6 compared to all other stages. There was a significant main effect of Rating point, $F(2, 34) = 14.86$, $p = 0.001$ ($\eta p^2 = 0.34$). The mean SUDS scores for each of the four rating points (with standard deviations in parentheses) was respectively 10.12 (13.43), 20.33 (14.20), 14.06 (11.32) and 8.96 (7.58). Pair wise comparisons of SUDS scores at each Rating point showed that scores increased from pre-exposure (0 ms) to 60 s and then decreased at 120 and 180 s respectively ($p < 0.0125$, Bonferroni corrected).

There was a significant Stage x Group x Rating point interaction (see Fig. 1), $F(4, 88) = 3.76$, $p = 0.006$ ($\eta_p^2 = 0.152$). This was analysed by examining the effects of Stage and Rating Point for each Group. For the low-fear group there were no significant main effects of Stage or Rating point and no significant interaction (Fig. 1). For the high-fear group, there was a significant Stage x Rating point interaction (Fig. 1), $F(4, 43) = 5.64$, $p = 0.001$ ($\eta_p^2 = 0.34$).

There were significant differences between consecutive rating points within each Stage ($p < 0.017$, Bonferroni corrected), with the exception of ratings between 0 and 60 s at Stage 6. Thus within each stage, mean SUDS scores increased from pre exposure to the first rating point (60 s), and then decreased at 120 and 180 s respectively. At Stage 6 when spider fearful individuals viewed the same image presented at Stage 1, there was no increase in SUDS ratings from pre exposure to 60 s post exposure, but there were significant decreases between 60-120 s and 120–180 s respectively.

One-way ANOVAS examining the effect of Stage at each Rating point revealed significantly lower SUDS ratings at Stage 6 compared to all other Stages at each of the post-exposure rating points (60, 120 and 180 s) but not at pre-exposure (0 s) ($p < 0.01$, Bonferroni corrected).

3.3. Event-related brain potentials

Stimulus-locked ERPs recorded at occipital sites were averaged across time points (0–60, 60–120, 120–180 s) for each of the six exposure stages for high and low spider fear groups (see Fig. 2). The P1 component peaked at approximately 100 ms post-stimulus onset and appears greater for the high-fear compared to the low-fear group across all exposure stages.

Analysis of peak P1 amplitude (see Fig. 3), revealed a significant main effect of Group, $F(1,21) = 6.04$, $p = 0.023$ ($\eta_p^2 = 0.22$), with higher P1 amplitude in the high-fear group ($M = 9.10$, $SD = 3.32$, compared to the low-fear group ($M = 5.68$, $SD = 3.35$). There was

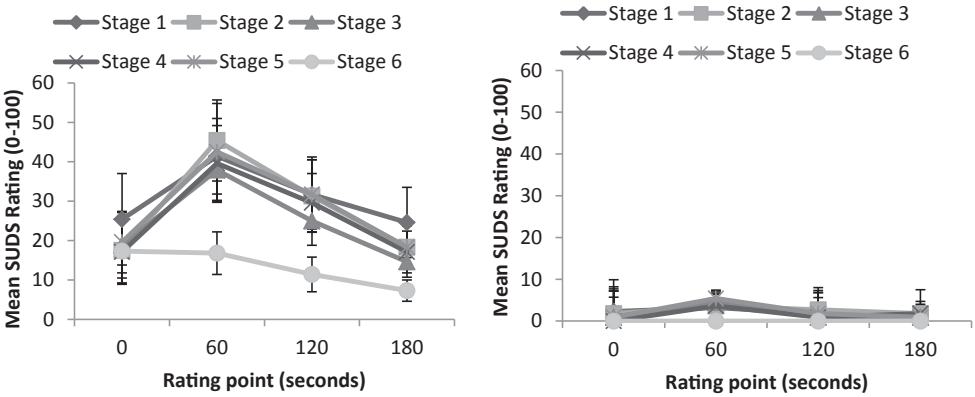

Fig. 1. Mean SUDS scores as a function of Stage and Rating point for high-fear (left) and low-fear (right) groups (error bars represent 95% Confidence intervals).

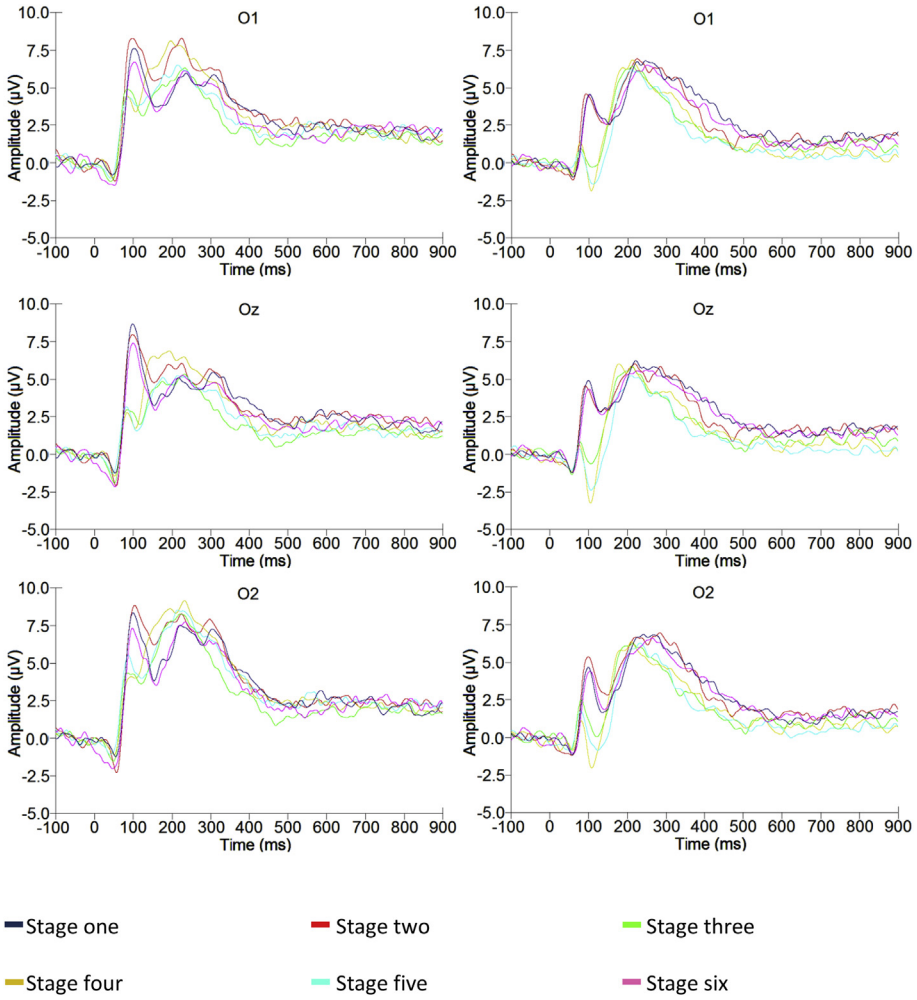

Fig. 2. Grand mean averaged ERPs at occipital Sites (O1, Oz, O2) for each stage of exposure for high ($n = 12$) and low-fear ($n = 11$) Groups.

also a significant main effect of Stage, $F(2, 35) = 6.46$, $p = 0.006$ ($\eta_p^2 = 0.24$). Pairwise comparisons across successive stages (Bonferroni adjusted $\alpha = 0.01$), revealed no significant difference between Stage 1 and 2, a significant decrease between Stages 2 and 3 ($p < 0.001$), no significant difference between Stages 3 and 4, or Stages 4 and 5, and a significant increase between Stage 5 and 6 ($p = 0.008$). A planned comparison comparing P1 amplitude at Stages 1 and 6 revealed no significant difference in P1 amplitude ($p = 0.077$).

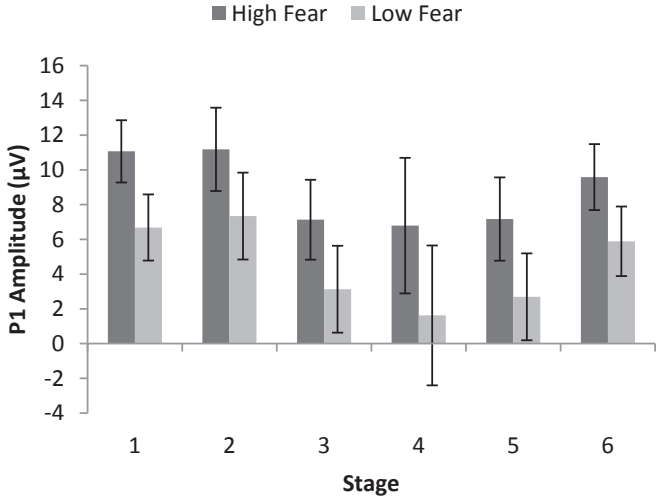

Fig. 3. Mean P1 amplitude for high-fear ($n = 12$) and low-fear ($n = 11$) groups during each exposure stage (error bars represent 95% Confidence intervals).

4. Discussion

As expected, spider fearful participants experienced greater subjective anxiety (SUDS ratings) across all stages of exposure compared to non-fearful participants. Furthermore, for Stages 1–5, high-spider fearfuls showed an increase in anxiety between pre-exposure and 60 s post-exposure and then a decrease in anxiety between 60-120 and 120–180 s. This demonstrates initial fear activation and within-stage habituation of subjective anxiety and is consistent with previous research using an online exposure program (Matthews et al., 2010, 2011, 2012, 2015). For high spider fearfuls, subjective anxiety decreased across successive stages, thus demonstrating between-stage habituation, and was significantly lower at Stage 6 compared to Stage 1 (both of which comprised the same image), suggesting that habituation of subjective anxiety was maintained over time. The group of low spider fearfuls did not demonstrate habituation of subjective anxiety, as their SUDS scores were initially low and stable across the stages, representing a floor effect.

As hypothesised, spider fearful participants showed greater P1 amplitude than the low-fear group across all exposure stages, which is consistent with previous findings of enhanced P1 amplitude among high fearful participants (Kolassa et al., 2006; Michalowski et al., 2009). This finding is likely to reflect enhanced attentional capture, or cortical hyper-vigilance, towards threat-related stimuli (Cisler & Koster, 2010; Pflugshaupt et al., 2005), a process which may be facilitated by amygdala projections to the visual cortex during threat-related hyperactivity (Bishop, 2007). Given the use of fear-relevant stimuli only in the present study, it is not possible to determine whether this finding reflects general or threat-specific hyper-vigilance in the high spider fearful group.

P1 amplitude decreased for both groups at Stages 3, 4 and 5, suggesting some habituation and generalisation of this early sensory response to different spider images. However, while it was expected that this effect would be greater for high relative to low fear participants, a similar pattern of between-stage habituation was found for both high and low fearful groups. Thus, habituation occurred for low spider fearfuls, despite their low levels of subjective anxiety. It is possible that this reflects a general habituation process associated with repeated exposure to stimuli. For example, multiple repetition of both pleasant and unpleasant stimuli also results in reduced amplitude of early (150–300 ms) and later (300–600ms) ERP components (Codispoti, Ferrari, & Bradley, 2006, 2007). Furthermore, P1 amplitude has been found to decrease following repetition of unpleasant pictures in normal participants (Olofsson & Polich, 2007). This suggests that, irrespective of the emotional relevance of stimuli, early sensory processes are impacted by repeated exposure to stimuli.

Unexpectedly, there was an increase in P1 amplitude at Stage 6, to the same level as observed at Stage 1, which was composed of the same spider image. This finding is in contrast to the significant reductions observed in self-reported anxiety between Stages 1 and 6 for the high-fear group. Interestingly, despite low self-reported anxiety throughout the task, the low spider fear group also demonstrated renewal of the P1 amplitude response at Stage 6, albeit still significantly lower overall in comparison to the high fear group. One possible explanation for the dishabituation of P1 amplitude at Stage 6, is that the repeated image may have re-activated stimulus-response associations that were initially activated at Stage 1. In previous research using the Implicit Association Test, both low and high spider fearfuls demonstrated that they associated spider images with anxiety-related words, with this effect marginally greater in high fearfuls (Ellwart, Rinck, & Becker, 2006). This was indexed by a reduction in the time taken to categorise spider images as spiders and anxiety-related words as unpleasant, when both of these categorisations required a response using the same key (Ellwart et al., 2006). Such fear associations may be facilitated by the amygdala, which has been implicated in the storage of fear memories (Kim, Pare, & Nair, 2013) and retrieval of these memories in response to fear-evoking stimuli (Ehrlich, Bush, & LeDoux, 2012). Furthermore, Craske et al. (2008) argues that extinction learning reduces, but do not erase, initial fear associations, and these can be readily re-activated. However, if initial stimulus representations were activated, automatic activation of subjective anxiety might also be expected, and this was not the case in the present study. Given that spider images likely represented negative but functionally neutral stimuli for the low spider fearfuls, who had very low subjective anxiety ratings in response to these images, it is possible that similar renewal of P1 amplitude may occur for neutral as well as for fearful stimuli, thereby representing a more general mechanism. Further research including fear-relevant, negative, and neutral images would be required to examine this further. It is also possible that high fear participants were influenced by demand characteristics when recording their SUDS ratings, and may have believed their anxiety was expected to decrease after repeated exposure to the spider images. This may have contributed to the findings of low subjective anxiety co-occurring with enhanced P1 amplitude at Stage 6.

An alternative explanation is that the reduction in P1 amplitude at Stages 3, 4, and 5 actually represented covert avoidance of images, as these were the scariest images in the hierarchy. In previous research, anxious participants have demonstrated faster covert shifts in attention (shifting focus without eye movement) away from threatening images relative to neutral images in a spatial cueing task, reflecting faster attentional disengagement (Ellenbogen & Schwartzman, 2009). However, the low spider fearful group also demonstrated this between-stage habituation of P1 amplitude at Stages 3, 4 and 5. As spider images likely represented negative but functionally neutral stimuli for the low spider fearfuls, it seems unlikely that they would have engaged in avoidance strategies. Again, further research using negative and neutral images is needed to evaluate this possibility.

As suggested above, given that both high and low spider fear groups showed similar habituation of P1 amplitude from Stages 1–5 and dishabituation at Stage 6, it is possible that the findings reflect a more generalised dishabituation mechanism. According to dual-process theory, dishabituation reflects a superimposed sensitisation process (increased responsiveness to novel stimuli) rather than disruption of habituation (Thompson, 2009). However, Steiner and Barry (2011) found that while sensitisation (as indexed by an increase in tonic skin conductance level) was found when participants passively listened to same-frequency tones followed by a deviant tone, this was independent from the emergence of dishabituation (as indexed by an increase in phasic skin conductance response). This suggests (in contrast to dual-process theory) that dishabituation occurs due to disruption to the habituation process, not sensitisation. Future research including neutral and fear-relevant images would be required to further examine these mechanisms in relation to the current finding of dishabituation of P1 amplitude.

The present findings suggest that habituation of anxiety during exposure to spider images does not necessarily correspond to reductions in a cortical measure of early attentional hyper-vigilance (P1 amplitude) among high spider fearfuls. Although the possible influence of demand characteristics is acknowledged, this finding may have practical and theoretical implications for the treatment of anxiety disorders in therapeutic settings. There have been conflicting results in terms of the effects of attention and distraction during exposure therapy. A recent meta-analysis indicated that while there was no difference between focused, distracted and uninstructed exposure on self-reported distress and physiological measures, there was a benefit of distraction in terms of therapeutic outcome at follow-up (Podina et al., 2013). Podina et al. (2013) suggest that distraction may benefit individuals with anxiety because they attribute reductions in their symptoms to the distraction. Alternatively, they suggest that it may reduce their ability to catastrophise about feared situations, leading to a reduction in anxiety. However, these findings are inconsistent with emotional processing and inhibitory learning theory, which argue for the importance of attentional focus (Podina et al., 2013) and other research showing that attention is important for extinction learning to occur (Liao, 2014). For example, in an emotional cuing paradigm involving fear conditioning to a white noise burst, following either attention towards or away from the CS in the extinction phase, there was greater extinction in the 'attend towards' than the 'attend away' condition (based on US expectancy ratings), but no differences in valence, arousal and threat ratings

of the CS, and only a short-lived RT effect (Van Bockstaele, Verschuere, De Houwer, & Crombez, 2010). However, in studies investigating the effects of attentional training on self-reported, behavioural, and implicit physiological measures of spider fear (Reese, McNally, Najmi, & Amir, 2010; Van Bockstaele et al., 2011), attentional training had no effects on therapeutic outcome variables. Furthermore, O'Toole and Dennis (2012) found that while attentional training reduced state anxiety regardless of whether participants were trained toward or away from threat, only the train away condition was associated with a reduction in P1 amplitude at post-training, and this occurred for both threatening and non-threatening stimuli. This finding adds weight to the possibility that participants in current study covertly avoided spider images during Stages 3, 4, and 5, where reductions in P1 amplitude were observed. However, in contrast to the present study, O'Toole and Dennis assessed P1 amplitude before and after attentional training, and not during training or exposure. The present results may indicate that attentional focus towards threat-stimuli, and alterations to attentional biases, are not critical for the attenuation of subjective anxiety to take place during graded exposure. Future research would need to examine the relationship between P1 amplitude during exposure and therapeutic outcome to test this.

A limitation of the present study is that a passive viewing paradigm was used, making it difficult to ascertain whether participants were attending to images during stages where decreased P1 amplitude was observed. Future studies could test this using a behavioural measure of performance or by use of eye tracking technology. In the present study, the repeated image enabled comparison of habituation processes before and after exposure to other images. While reductions in P1 amplitude were expected to occur over time, given the limited time interval between each exposure stage, P1 amplitude is more likely to reflect short-term habituation/dishabituation processes rather than the long-term effects of exposure. It was not a primary aim to examine therapeutic response to exposure in the present study, therefore conclusions regarding the relationship between attentional mechanisms and outcome is not possible, and future research would be required to examine this further among larger samples of people with clinically diagnosed specific phobia.

In conclusion, image-based exposure to fear-relevant images resulted in habituation of subjective anxiety within and between stages of exposure for high spider fearfuls. Spider fearful individuals also showed greater P1 amplitude compared to the low-fear group, consistent with enhanced attentional hyper-vigilance. While P1 amplitude habituated at early stages of the exposure hierarchy for both groups, P1 amplitude increased in both groups when the original spider image from stage 1 was presented at stage 6. This occurred without a concomitant increase in subjective anxiety among high spider fearfuls, and despite low and stable subjective anxiety among low fearfuls. These findings indicate that habituation of subjective anxiety is not necessarily accompanied by reductions in P1 amplitude. Possible explanations for the renewal of the P1 amplitude at Stage 6 include a renewal of associations initially activated at Stage 1, greater covert avoidance at Stages 3, 4, and 5 where spider images were scarier, or a general dishabituation mechanism. Future research examining the relationship between therapeutic outcome and modification of attentional biases is required to examine the significance of P1 habituation and dishabituation processes.

5. Conflicts of interest

There are no conflicts of interest to be declared.

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