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ORIGINAL PAPER

The relationship between self-reported animal fear and ERP modulation: Evidence for enhanced processing and fear of harmless invertebrates in snake- and spider-fearful individuals

Kimberley M. Mallan · Ottmar V. Lipp

Abstract The present study used ERPs to compare processing of fear-relevant (FR) animals (snakes and spiders) and non-fear-relevant (NFR) animals similar in appearance (worms and beetles). EEG was recorded from 18 undergraduate participants (10 females) as they completed two animal-viewing tasks that required simple categorization decisions. Participants were divided on a post hoc basis into low snake/spider fear and high snake/spider fear groups. Overall, FR animals were rated higher on fear and elicited a larger LPC. However, individual differences qualified these effects. Participants in the low fear group showed clear differentiation between FR and NFR animals on subjective ratings of fear and LPC modulation. In contrast, participants in the high fear group did not show such differentiation between FR and NFR animals. These findings suggest that the salience of feared-FR animals may generalize on both a behavioural and electro-cortical level to other animals of similar appearance but of a non-harmful nature.

Keywords Fear · Fear relevance · Event-related brain potentials · Generalization

Introduction

Humans and other animals have a tendency to respond fearfully to spiders and snakes. Indeed, specific phobia of spiders is the most prevalent (3.5% prevalence rate) animal-related phobia in humans and is notably higher in women than in men (Gerdes et al. 2009; Jacobi et al. 2004). These observations have been explained in terms of Seligman's (1970, 1971) preparedness hypothesis, which proposes that some stimuli in our environment are especially prepared to enter into aversive associations that produce strong, robust phobic fear responses. Preparedness to acquire a strong and persisting fear of threatening or fear-relevant (FR) stimuli through an aversive learning experience is thought to have been evolutionarily adaptive to the survival of our ancestors. Extending on Seligman's (1970, 1971) preparedness hypothesis, Öhman and Mineka (2001) proposed a fear module account of human phobias. Evolutionarily FR stimuli were argued to elicit learned fear that is (a) limited to a discrete set of conditional and unconditional stimulus combinations (Öhman et al. 1976), (b) acquired after a single learning episode (Öhman et al. 1975a), (c) resistant to extinction (Öhman et al. 1975b), and (d) irrational and unaffected by cognitive influences (Hugdahl and Öhman 1977; Lipp and Edwards 2002).

The propensity for FR stimuli to become associated with fear has been linked back to the well-established finding that FR stimuli have access to preferential attentional processing relative to non-fear-relevant (NFR) stimuli. The visual search paradigm has been used by a number of different research groups to demonstrate this: snakes and spiders are identified faster in a background of NFR stimuli (flowers/mushrooms or birds/fish) than vice versa (Lipp 2006; Öhman et al. 2001). Although the majority of visual search studies have used an "active search" task, Lipp and Waters (2007) replicated the basic finding of preferential attentional processing of FR stimuli in a "passive attention" search task (see Graham and Hackley 1991). Search time for a neutral target animal in

K. M. Mallan (✉) · O. V. Lipp
School of Psychology, University of Queensland,
St. Lucia, QLD 4072, Australia
e-mail: mallan@psy.uq.edu.au

O. V. Lipp
e-mail: o.lipp@psy.uq.edu.au

a background of neutral animals was significantly slowed in the presence of a FR distractor (snake or spider) than in the presence of a NFR distractor (big lizard or cockroach). Furthermore, this preferential attentional capture effect was strongest in the presence of a feared-FR distractor (e.g., a spider for spider-fearful participants). A similar finding has been reported in a dot probe attention task. Lipp and Derakshan (2005) found evidence for preferential processing of FR animals in unselected participants: response latencies were shorter to probes that replaced FR animals (spiders and snakes) than to probes that replaced NFR stimuli. Moreover, the attentional bias to spider stimuli was exaggerated in participants who reported higher levels of spider fear, but was still present in participants with lower levels of spider fear.

Evidence for preferential processing of FR stimuli has also been shown when visual stimuli were presented backwardly masked and therefore not consciously perceived by participants. Phobic participants showed elevated electrodermal responding to masked presentations of their feared-FR stimulus compared to masked presentations of a not-feared-FR stimulus or a NFR stimulus (Öhman and Soares 1994). Similarly, unselected participants showed differential electrodermal responding to masked conditional stimuli following training with FR stimuli, but not NFR stimuli (Esteves et al. 1994; Flykt et al. 2007).

A covariation bias has been suggested as a mechanism that may facilitate learning of fear to FR stimuli and support resistance to extinction (Tomarken et al. 1989). A study by Mühlberger et al. (2006) compared covariation bias and physiological responsiveness in spider phobics and aviophobics (flight phobics) in an illusory correlation experiment involving pictures of their feared stimulus (spiders or plane crash scenes) and a neutral stimulus (mushrooms), as well as random presentations of a startling noise. Prior to the illusory correlation procedure, both spider phobics and aviophobics displayed an expectancy bias that their feared stimulus would be associated with negative outcomes and showed enhanced electrodermal responses to the disorder-specific stimulus. However, following the illusory correlation procedure, spider phobics exclusively showed a covariation bias and stronger physiological responding (i.e., fear-potentiated startle and enhanced event-related potentials [ERPs]) to spiders. These results suggest that feared-FR stimuli, in particular phylogenetically relevant threat stimuli, are processed in a strongly biased fashion. This conclusion is in accord with evidence from studies of preferential attentional processing of FR stimuli in visual search (Lipp 2006; Lipp and Waters 2007; Öhman et al. 2001) and dot probe (Lipp and Derakshan 2005) paradigms as well as investigations that have assessed measures of electro-cortical activity.

Event-related potentials (ERPs) have been employed in a number of studies to investigate differences in the processing of FR and NFR stimuli in both unselected and phobic participants (e.g., Kolassa et al. 2005, 2006; Miltner et al. 2005; Schienle et al. 2008). It has been shown in both unselected and spider phobic participants that pictures of real and schematic spiders elicit enhanced P3 and LPC relative to neutral pictures (Schienle et al. 2008). Investigations into individual differences in the processing of these FR animals between spider phobic participants and controls have consistently found that phobic participants display larger P300 and/or LPC to spider pictures (Kolassa et al. 2005; Miltner et al. 2005; Schienle et al. 2008). Furthermore, whereas spider pictures and other fear-inducing pictures have been shown to elicit similar LPC amplitudes in non-phobic participants, a larger LPC to spiders relative to other fear-inducing pictures has been observed in phobic participants (Kolassa et al. 2006).

The event-related potential technique allows researchers to observe—with high temporal resolution—electro-cortical brain activity that reflects specific cognitive processes. Components of the ERP waveform can be affected by processes such as perception, memory, expectation, attention and emotional evaluation. The late positive potential/complex (LPP/LPC) is understood to reflect a range of psychological processes, including evaluative processes, and has been the component of interest in many studies looking at the processing of affective stimuli, including phobic FR stimuli. In line with past research on the processing of emotional stimuli, including FR animals, our analysis of ERPs will focus exclusively on modulation of the LPC. Typically, the LPC is potentiated when processing emotionally arousing stimuli relative to neutral stimuli (Schupp et al. 2004). This emotional modulation is thought to reflect on deeper processing of motivationally salient stimuli as these are said to draw more attentional resources and are selectively processed. Functional and evolutionary considerations suggest the benefit of selective processing of emotional cues to facilitate adaptive behaviours, thereby promoting survival and reproductive success.

The present study used modulation of the LPC component of the ERP waveform to compare motivated attentional processing of FR animals (snakes and spiders) and appearance-matched NFR control animals in a group of unselected participants who were divided based of self-reports into a low and a high snake and spider fear group. Whereas previous studies have used stimuli such as flowers and mushrooms as NFR controls, we endeavoured to match FR animals to similar-in-appearance NFR animals. Thus, pictures of worms were used as a NFR control for snakes, and beetles were chosen as a NFR control for spiders. Furthermore, the FR and NFR stimuli were similarly different to the "background" stimuli—pictures of horses, cats, dogs and deer. The task required participants to categorize pictures based on a physical characteristic, whether or not the animal had four legs. Consequently, the FR and NFR animals of interest were always categorized together. As such, any differences in the motivated attentional processing of FR and NFR animals revealed through comparison of the LPC component can be more confidently attributed to stimulus "fear relevance" rather than to gross differences in physical appearance or explicit task demands. Assuming that FR stimuli do receive greater attentional processing than NFR stimuli we predicted that LPC mean amplitude would be larger in response to pictures of FR animals than to the similar-in-appearance NFR animals.

Another advantage of using worms and beetles as NFR stimuli was the potential to investigate individual differences in processing not only FR animals (snakes and spiders) but other NFR "creepy crawlies" in participants reporting lower or higher levels of snake and spider fear. Self-report data suggest that high spider fearful individuals are also more fearful of other creepy crawlies such as wasps/bees, beetles and butterflies/moths (Gerdes et al. 2009). It has been postulated that cultural stereotypes bias verbal labelling of spider fear and may occlude the more generalized nature of fear (and disgust) responses to of other creepy crawlies (e.g., invertebrates such as arthropods, as well as reptiles and rodents; Davey 1992). Thus, we were curious as to whether participants with higher levels of snake and spider fear would report elevated fear of worms and beetles and whether evidence for this generalization of fear would be reflected in ERPs, specifically potentiation of the LPC. We predicted that when compared to participants with lower fear of snakes and spiders, participants with higher snake and spider fear would report greater fear of the other creepy crawlies (worms and beetles), but not other mammals (dogs, cats, horses, and deer). If this were the case, we also would predict an interaction between snake and spider fear (high vs. low) and the fear relevance of the creepy crawly stimuli (FR: spiders and snakes vs. NFR: worms and beetles) such that participants with less fear of snakes and spiders may show differential LPC responses to FR and NFR animals whereas participants with greater fear of snakes and spiders (and predicted greater fear of worms and beetles) would show less clear differentiation of LPC responses to FR and NFR stimuli such that LPC mean amplitude may appear elevated for the snakes and spiders as well as for the worms and beetles. Again, it is predicted that these differences in responding to FR and NFR creepy crawlies would not be present if we examine LPC responses to mammalian animals.

Method

Participants

Nineteen students (11 females, 8 males; aged 18–25 years, $M = 21.21$, $SD = 2.10$) from the University of Queensland provided informed consent to participate in the study and were paid AUS$20 remuneration. All participants were right-handed, had normal or corrected-to-normal vision, reported no history of mental illness, head injury, epilepsy or illicit drug use and were not currently taking medication (other than the contraceptive pill). Participants completed pen-and-paper versions of the Snake (SNAQ; 30 items) and Spider (SPQ; 31 items) Fear Questionnaires (Klorman et al. 1974), which were designed to tap specific fears of snakes and spiders and were used to create post hoc low fear and high fear groups. The SPQ was scored out of 31, with the mean score being 14.00 ($SD = 8.09$), whereas the SNAQ was scored out of 30, with the mean score being 12.89 ($SD = 7.34$). SPQ and SNAQ scores correlated highly: Pearson correlation $= .62$, $p = .006$. Participants were split into two groups: if both their SPQ and SNAQ scores were below the mean on the respective scale, they were allocated to the low fear group, whereas if both their SPQ and SNAQ scores were above the mean on the respective scale, they were allocated to the high fear group. This resulted in eight participants in the low fear group (5 females, 3 males) and nine participants in the high fear group (4 females, 5 males). Two participants who scored above the mean on the SPQ/SNAQ and below the mean on the SNAQ/SPQ were excluded from all subsequent analyses. Rating data from one participant in the high fear group was incomplete so this participant was excluded from analyses of the rating data, but was included in the ERP analysis.

Stimuli

Pictorial stimuli consisted of a set of 72 greyscale photographs of eight different animal categories, with nine pictures per category. Four of the animal categories were relevant to the purposes of the study: beetles, spiders, snakes, and worms, and the other four categories were not relevant to the study: cats, dogs, deer, and horses. The four relevant categories were defined in terms of two independent factors: (1) Fear relevance, and (2) Appearance. Spiders and snakes were used as fear-relevant stimuli and worms and beetles served as non fear-relevant stimuli. Spiders and beetles served as stimuli spider-like in appearance, whereas snakes and worms served as stimuli snake-like in appearance. All pictures were sourced from the internet and resized to 426 × 341 pixels. All pictures depicted the entire creature against various backgrounds (plain grey, nature scenes, etc.). The pictorial stimuli were presented in the centre of a 17 inch CRT (Samsung Multisync) computer screen with a resolution of 1,280 × 1,024 pixels.

Procedure

Each participant read and signed an informed consent form, read a standard instruction sheet and completed the Edinburgh Handedness Inventory (Oldfield 1971) and a custom-designed medical history questionnaire prior to the experiment. Anyone with a history of head injury, epilepsy or illicit drug use, or anyone currently taking medication (other than the contraceptive pill) was excluded from participation. The age and sex of each participant were recorded. The participant was seated facing a 17 inch CRT monitor in a sound-attenuated experimental room adjacent to the experimenter's control room. The participant then completed the SPQ and SNAQ.

Prior to application of the electrode cap (32 channel Quick Cap, sintered Ag/AgCl electrodes, Neuroscan), the experimenter cleaned the participant's skin where the mastoid reference electrodes and the VEOG and HEOG electrodes were to be placed with alcohol wipes and abraded with NuPrep. Electrodes were filled with Surgicon electrolyte gel.

The task instructions were given to the participants verbally and participants completed a short set of practice trials that were the same as the experimental trials detailed below. They were presented with two experimental tasks (A and B) in an order counterbalanced across participants. Each task consisted of 200 trials. In task A, the participant was instructed to press a response button when the animal presented belonged to a species that has four legs and to withhold their response when the animal belonged to a species that does not have four legs. In task B the instructions were the opposite, thus the participant pressed the response button when the animal belonged to a species that does not have four legs and withheld their response when the animal presented belonged to a species that has four legs. Each trial began with a fixation cross for ~300 ms, followed by the pictorial stimulus for ~1,200 ms. Inter-trial intervals varied randomly between 2,000 and 2,200 ms. In both tasks, there were 25 presentations for each species, thus each individual picture was presented either two or three times during each task. Presentation of the pictorial stimuli and recording of behavioural data was controlled by DMDX (Forster and Forster 2003).

Post-experimental ratings of animal fear, pleasantness, and arousal were collected following the two categorization tasks using a pen-and paper questionnaire. Participants indicated on a scale of 1–9 (1 = not feared, 9 = very feared) the level of subjective fear of each of the eight categories of animals as listed on the response sheet. The order of the animal categories was randomized across participants. The same response format was used for ratings of animal pleasantness (1 = very unpleasant to 9 = very pleasant) and arousal (1 = not arousing to 9 = very arousing).

EEG recording and ERP analysis

EEG activity was recorded using Neuroscan SCAN 4.3.1 software and Synamps 1 amplifiers. EEG activity was recorded from 32 electrodes placed according to the International 10–20 system (Jasper 1958) with a Quick-cap containing sintered Ag–AgCl electrodes. All electrode sites were referenced to linked mastoids. Horizontal and vertical EOG activity was recorded. EEG activity was sampled continuously at 1,000 Hz and amplified with a high pass filter of 0.15 Hz, and a low pass filter of 100 Hz. Ocular artefact rejection was conducted to correct for EOG interference, and blocks affected by other sources of noise were removed (i.e., larger than normal EOG activity (>160 μV), excessive noise due to EMG activity, EKG activity, alpha waves, or skin potentials in any of the EEG channels, and different-to-usual EOG activity including saccades). Data were band pass filtered between 0.15 and 30 Hz at 24 dB per octave. Continuous data files were divided into 1,600 ms epochs commencing 100 ms prior to stimulus onset and baseline corrected. High and low voltage cut-offs for artefact rejections were set at 100 and −100 μV, respectively.

EEG epochs for correct trials only were averaged. Grand mean averaged waveforms were calculated separately for snake, spider, worm and beetle pictures at each electrode site. Visual inspection of these four grand mean ERP waveforms across the five midline electrode sites led to the identification of a LPC. Mean amplitude (μV) of the LPC for each animal category was calculated in the post-stimulus onset latency windows of 450–650 ms. ERP mean amplitudes for the LPC were analyzed in a 2 × 2 × 2 × 2 × 5 × 3 (Group [low fear vs. high fear] × Task [A vs. B] × Fear relevance [FR vs. NFR] × Appearance [snake-like vs. spider-like] × Midline × Coronal) mixed model ANOVA. The multivariate solution (Pillai's Trace) was interpreted for all analyses and significant interactions were followed-up with Bonferroni corrected *t* tests.

Results

Task accuracy

Accuracy on both tasks was very high: 93% on the "four legs" task and 91% on the "not four legs" task. The

2 × 2 × 8 (Group × Task × Animal) factorial ANOVA of response accuracy revealed no significant effects or interactions assessed against the critical value for significance, $p = .05$.

Rated fear

Fear, pleasantness, and arousal ratings of the four animal categories of interest (worm, snake, spider and beetle) were subjected to separate 2 × 2 × 2 (Group × Appearance × Fear relevance) repeated-measures ANOVAs. The analysis of the fear ratings yielded a main effect for Fear relevance, $F(1, 14) = 56.04$, $p = 2.94^{-6}$, $\eta_p^2 = .80$, and Group, $F(1, 14) = 60.06$, $p = .002$, $\eta_p^2 = .52$. Of particular interest was the Fear relevance × Group interaction, $F(1, 14) = 6.92$, $p = .02$, $\eta_p^2 = .33$. As illustrated in Fig. 1 (upper panel), participants allocated to the high fear group rated both FR ($M = 7.06$, SD = 1.17) and NFR ($M = 5.57$, SD = 1.44) animals as more feared compared to ratings of FR ($M = 5.94$, SD = 1.29) and NFR ($M = 2.81$, SD = 1.62) animals by participants in the low fear group, $t(14) = 3.641$, $p = .05$, and $t(14) = 8.900$, $p = .001$, respectively. Nevertheless, both groups rated FR stimuli as significantly more feared that NFR stimuli; low fear group, $t(14) = 10.11$, $p = 4.91^{-6}$, and high fear group, $t(14) = 4.85$, $p = .004$.

To check for potential between-group differences in fear of animals generally, the fear ratings obtained for the "background" animals (i.e., dog, cat, horse and deer) were subjected to the same analysis as described above for the animal categories of interest. In contrast to the previous between-group differences in fear ratings, no main effects or interactions reached the critical value for significance, $p = .05$. For a complete list of mean fear ratings (and SDs) for all eight animal categories as a function of fear group membership, please refer to Table 1.

Rated pleasantness

Pleasantness ratings of worms, snakes, beetles and spiders are presented in the middle panel of Fig. 1. Main effects for Appearance, $F(1, 14) = 19.18$, $p = .001$, $\eta_p^2 = .58$, and Fear relevance, $F(1, 14) = 9.05$, $p = .009$, $\eta_p^2 = .39$, were subsumed by a Appearance × Fear relevance interaction, $F(1, 14) = 5.31$, $p = .04$, $\eta_p^2 = .28$. Spiders were rated as less pleasant than their appearance matched control—beetles, $t(14) = 7.81$, $p = .002$. Snakes and worms, however, were rated as equally unpleasant, $t(14) = 3.20$, $p = .15$. Snakes and spiders were rated as equally unpleasant, $t(14) = 2.84$, $p = .10$, however beetles were rated as more pleasant than worms, $t(14) = 7.46$, $p = 1.91^{-4}$ (Table 2).

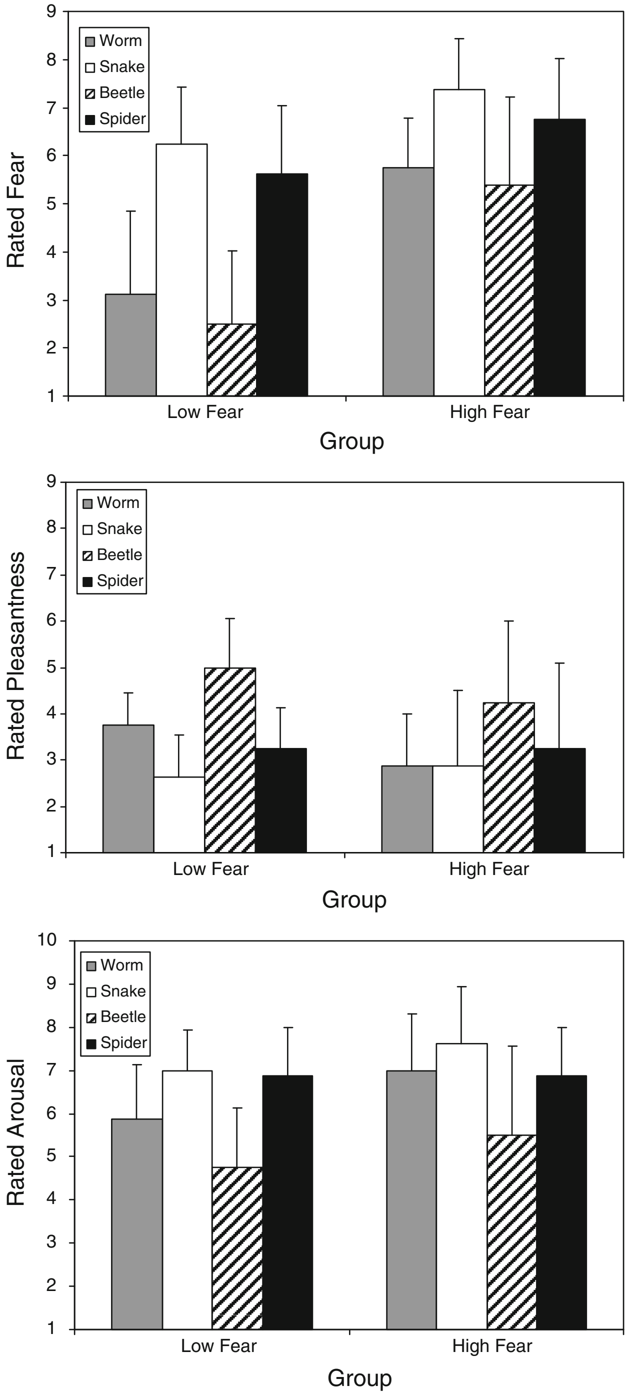


Fig. 1 Post-experiment ratings (*M*s and SDs) of worms, snakes, beetles and spiders on dimensions of fear (*upper panel*), pleasantness (*middle panel*) and arousal (*lower panel*) by participants assigned to the low fear or high fear group

Rated arousal

Arousal ratings of the four species are presented in the lower panel of Fig. 1. Fear-relevant stimuli were rated more arousing than NFR stimuli. Inspection of the figure

Table 1 Post-experimental ratings of animal fear (*M*s + SDs)

Group	Animal							
	Worm	Snake	Beetle	Spider	Cat	Dog	Horse	Deer
Low fear	3.125 (1.727)	6.250 (1.165)	2.500 (1.512)	5.625 (1.408)	.750 (.886)	.750 (.463)	1.375 (.916)	2.000 (2.330)
High fear	5.750 (1.035)	7.375 (1.061)	5.375 (1.847)	6.750 (1.282)	1.750 (1.165)	1.500 (1.690)	1.375 (1.302)	2.000 (1.195)

Table 2 Post-experimental ratings of animal pleasantness (*M*s + SDs)

Group	Animal							
	Worm	Snake	Beetle	Spider	Cat	Dog	Horse	Deer
Low fear	3.750 (.707)	2.630 (.916)	5.000 (1.069)	3.250 (.886)	7.380 (1.188)	8.130 (.835)	7.380 (1.188)	6.250 (1.165)
High fear	2.880 (1.126)	2.880 (1.642)	4.250 (1.753)	3.250 (1.832)	7.630 (1.408)	8.130 (.835)	7.750 (1.035)	7.380 (.916)

Table 3 Post-experimental ratings of animal arousal (Ms + SDs)

Group	Animal							
	Worm	Snake	Beetle	Spider	Cat	Dog	Horse	Deer
Low fear	5.880 (1.246)	7.000 (.926)	4.750 (1.389)	6.880 (1.604)	4.500 (1.604)	4.380 (2.825)	3.880 (2.167)	3.750 (2.500)
High fear	7.000 (1.309)	7.630 (1.302)	5.500 (2.070)	6.880 (1.126)	2.380 (1.061)	2.000 (1.069)	2.113 (1.356)	1.581 (.926)

suggests that appearance also played a part such that worms were more arousing than beetles and snakes more arousing than spiders. These impressions are supported by main effects for Fear relevance, $F(1,\ 14) = 24.31$, $p = 2.21^{-4}$, $\eta_{\mathrm{p}}^2 = .64$, and Appearance, $F(1,\ 14) = 9.66$, $p = .008$, $\eta_{\mathrm{p}}^2 = .41$. All other effects and interactions did not reach the critical value for significance, $p = .05$ (Table 3).

ERP modulation: LPC mean amplitude

The LPC elicited on worm, snake, beetle and spider trials (averaged across tasks) can be seen in the grand mean waveforms at Fz (Fig. 2, upper panel), Cz (Fig. 2, middle panel) and Pz (Fig. 2, lower panel). Examination of the three panels of Fig. 2 shows that LPC mean amplitude was larger at parietal than frontal sites; main effects for Midline, $F(4,\ 12) = 9.42$, $p = .001$, $\eta_{\mathrm{p}}^2 = .758$. LPC mean amplitude was larger over the midline than over the right or left hemisphere; main effect for Coronal sites, $F(2,\ 14) = 4.74$, $p = .03$, $\eta_{\mathrm{p}}^2 = .40$. The LPC was significantly modulated by fear relevance, specifically, LPC mean amplitude was larger in response to FR animals ($M = 2.81$, $SD = 3.91$) than to NFR animals ($M = 1.86$, $SD = 3.01$), $F(1,\ 15) = 5.18$, $p = .04$, $\eta_{\mathrm{p}}^2 = .26$. This effect was qualified by a significant Group × Fear relevance interaction, $F(1,\ 15) = 4.74$, $p = .05$, $\eta_{\mathrm{p}}^2 = .24$.

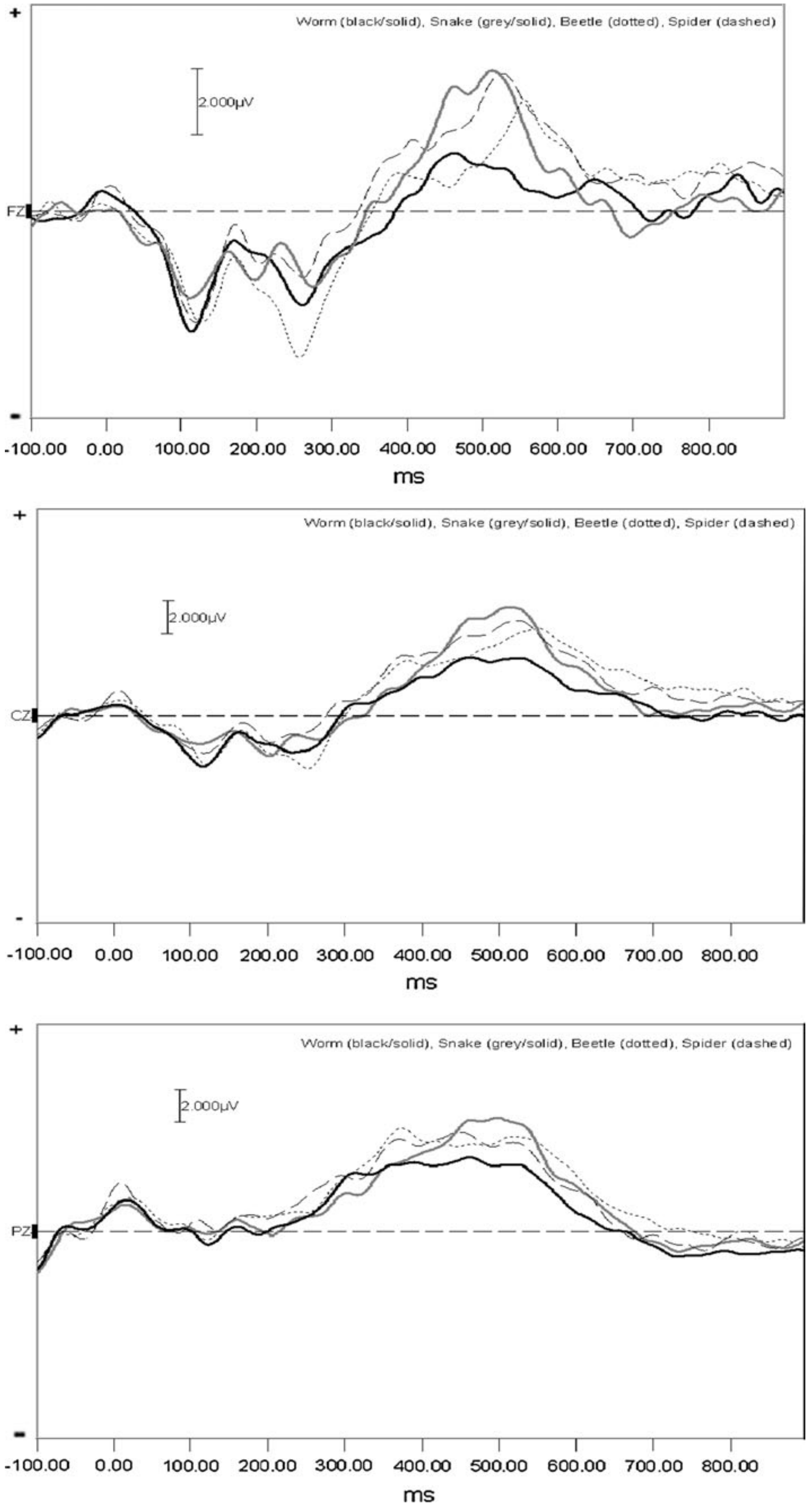
As illustrated in Fig. 3, LPC was larger to FR animals ($M = 2.707$, $SD = 3.361$) than to NFR animals ($M = .75$, $SD = 3.10$) only in the low fear group, $t(15) = 4.51$, $p = .008$. LPC mean amplitude shown by participants in the high fear group was similar in response to FR ($M = 2.89$, $SD = 4.11$) and NFR animals ($M = 2.85$, $SD = 2.61$), $t(15) = .10$, $p = .94$. This lack of difference in response to pictures of FR and NFR animals in the high fear group appears to be driven by enhanced LPC to NFR animals which was significantly larger in the high fear group ($M = 2.85$, $SD = 2.61$) than in the low fear group ($M = .75$, $SD = 3.10$), $t(15) = 4.87$, $p = .04$. It does not reflect on between group differences in overall electro-cortical responding since mean amplitude of the LPC to FR animals did not differ between groups, $t(15) = .33$, $p = .87$.

The LPC mean amplitudes to the "background" animals (i.e., dogs, cats, horses and deer) were also analyzed in the $2 \times 2 \times 2 \times 2 \times 5 \times 3$ (Group × Task × Appearance × Fear relevance × Midline × Coronal) mixed model ANOVA whereby values for spiders and snakes were substituted with values for dogs and cats, and values for worms and beetles were substituted with values for horses and deer. No main effects or interactions involving the between-group factor (high vs. low fear) reached the critical value for significance, $p = .05$.

Discussion

Event-related potential methodology coupled with subjective ratings of animal fears was used to investigate the

Fig. 2 Grand mean ERP waveforms on worm, snake, beetle and spider trials averaged across both tasks and groups at Fz (*upper panel*), Cz (*middle panel*) and Pz (*lower panel*)



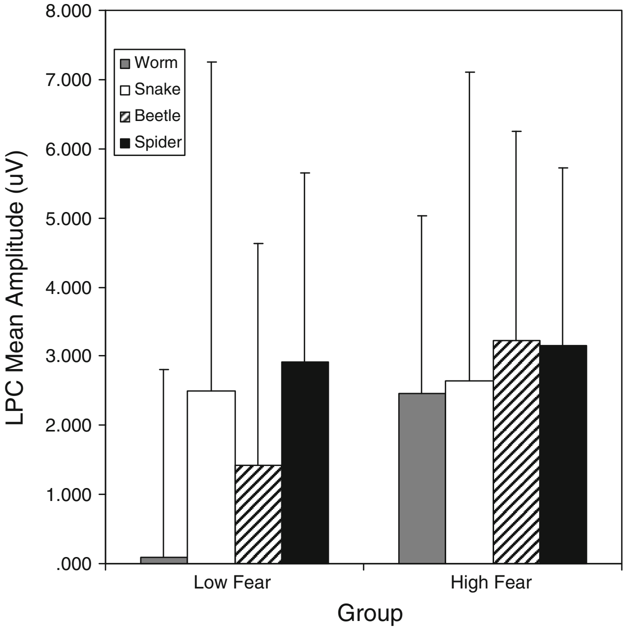


Fig. 3 Average late positive complex (*LPC*) mean amplitude (+SDs) to worm, snake, beetle and spider stimuli (collapsed across tasks) by participants assigned to the low fear or high fear group

relationship between individual differences in self-reported animal fear and an electro-cortical correlate of motivated attentional processing (i.e., LPC modulation). Two key questions were addressed. Firstly, whether FR and appearance-matched NFR animal stimuli would elicit differential LPC responses in line with expectations of previous research on potentiation of this ERP component by emotional and/or FR stimuli. Secondly, whether individual differences in fear of snakes and spiders differentially affected reported fear of similar-in-appearance NFR animals and LPC modulation. Whereas previous studies have frequently used stimuli such as flowers and mushrooms as NFR controls (but see Carretié et al. 2009; Lipp and Waters 2007), the present study employed pictures of worms and beetles as NFR controls for FR snakes and spiders. Unselected participants completed a simple categorization task while EEG was recorded and then rated the animals in terms of fear, pleasantness, and arousal. Participants were allocated to either a lower snake and spider fear group ("low fear group") or a higher snake and spider fear group ("high fear group") based on scores on the SPQ and SNAQ (Klorman et al. 1974) to allow exploration of the potential impact of levels of snake and spider fear on the motivated attention toward, and subjective fear of, FR and NFR animals.

Based on previous literature we focused on the LPC of the ERP waveform as an index of the degree to which the animal stimuli recruited attentional processing resources and can be considered as motivationally salient stimuli to the participant. The present results indicated between group differences in LPC modulation to FR and NFR animals. On the one hand, participants who reported lower levels of snake and spider fear showed the expected pattern of differential LPC to the FR and appearance-matched NFR animals; specifically, larger LPC elicited on FR trials compared to NFR trials. On the other hand, participants who reported relatively higher levels of snake and spider fear failed to show such a differentiation. To check that this result did not simply reflect on greater LPC modulation to all animal stimuli by high fear participants, we analyzed LPC mean amplitudes to the four categories of background (mammalian) animals (cats, dogs, deer and horses) also presented in the experimental tasks. No evidence was found to support the idea that there was an overall difference in how low fear and high fear participants processed animal pictures since a between-group effect was not found, nor were any interactions involving the group factor significant.

The pattern of LPC modulation observed in the low fear group is consistent with previous ERP studies that report LPC facilitation to FR stimuli and other unpleasant (i.e., fear- or disgust-eliciting) stimuli compared to neutral stimuli (Miltner et al. 2005; Schienle et al. 2008; Schupp et al. 2000, 2004). Facilitation of the LPC in this context is taken to reflect on the motivational salience of the FR animals and hence, deeper attentional processing of FR stimuli compared to NFR controls. These findings are also consistent with the notion that FR stimuli receive preferential attentional processing even in unselected participants (Lipp 2006; Lipp and Waters 2007; Öhman et al. 2001).

Interpretation of the finding that participants in the high fear group showed undifferentiated LPC responses to the FR and NFR animals is less straightforward. Although LPC mean amplitudes to the snakes and spiders were comparable to those observed in the low fear group, LPC mean amplitudes to the worms and beetles were significantly larger than in the low fear group. This result suggests that to the high snake and spider fearful participants, both the FR and NFR animals were motivationally salient and consequently engaged relatively deep attentional processing. Why this may be the case is unclear although the rating data provide some insights.

Participants in the low fear group rated snakes and spiders as significantly more fear-eliciting than worms and beetles. Participants in the high fear group also rated FR animals as more fear-eliciting than NFR animals, but rated snakes and spiders, as well as worms and beetles, as more fear-eliciting than did participants in the low fear group. In fact, the high fear group rated the harmless invertebrates (worms and beetles) as equally feared as the low fear group rated the potentially dangerous FR spiders and snakes. Taken together, these findings are in accord with a recent study by Gerdes et al. (2009) which found spider phobics rated not only spiders, but also other arthropods as more feared than did controls. As expected participants' rated fear of the mammalian stimuli (dogs, cats, horses and deer) did not reveal between group differences. The present study did not find differences between the low and high fear participants in pleasantness and arousal ratings of the FR and NFR animals but as expected the FR animals were rated as less pleasant and more arousing than the NFR animals.

The absence of clear LPC differentiation between the FR and NFR animals observed in the high fear group may be due to greater motivated attentional processing of NFR animals that share certain features with, or are similar in appearance to feared-FR animals. The degree of overlap in terms of physical features/characteristics between the FR and NFR animals used in the present study may have been sufficient to capture or engage the attention of those participants more sensitive to the threat relevance of the FR stimuli. It has previously been suggested that preferential attentional processing of FR stimuli (Öhman and Mineka 2001) and NFR stimuli (Purkis and Lipp 2009) may facilitate fear learning mechanisms which increase fear responding to such stimuli. Taken together, we can speculate on the existence of a link between enhanced attentional processing of the worms and beetles and the observation that participants in the high fear group were significantly more afraid of worms and beetles than participants in the low fear group and feared these animals as much as participants in the low fear group feared snakes and spiders (see also Gerdes et al. 2009).

Alternatively, participants with higher snake and spider fear may have a tendency to judge animals that are similar in appearance to feared-FR animals as snake- or spider-like and therefore, potentially threatening and worthy of increased attentional processing. Drawing on findings from the social phobia literature, Kolassa et al. (2007) investigated whether spider phobic participants would show an interpretative bias similar to that shown by individuals with social phobia who are more likely to misinterpret ambiguous social situations as threatening. In a task that required participants to judge whether pictures were more similar to a spider or a flower as the pictorial stimuli transformed (via gradual morphing) from a schematic flower into a schematic spider, spider phobic participants showed a significant interpretative bias. In addition to the behavioural data, ERPs during stimulus presentations were analyzed and although the spider phobics showed an interpretative bias on the behavioural level, electro-cortical correlates of this bias could not be identified in the ERP waveforms. This outcome casts doubt on the notion that enhanced LPC amplitudes to worm and beetles in the high fear group are the result of an interpretative bias. Moreover, there is no direct evidence from the present study to indicate that the pictures of worms and beetles were ambiguous. As such, it seems that the facilitated LPC in response to these NFR animals in high fear participants was not due to the pictures of worms/beetles being misinterpreted or mistaken for pictures of snakes/spiders.

Nevertheless, the question remains as to why the high fear participants in the present study did not show even greater LPC modulation to the FR stimuli? This would be expected based on evidence that spider phobic participants show a larger LPC to spider pictures relative to other fear-inducing pictures (Kolassa et al. 2006) and flower-spider morphed pictures (Kolassa et al. 2007). The relatively low sample size of the present study needs to be taken into account when interpreting this non significant effect (i.e., a lack of difference in LPC between FR and NFR stimuli in the high fear group). Future studies with phobic participants may be useful for determining whether LPC is enhanced to FR stimuli such as spiders relative to similar-in-appearance NFR such as beetles, and quite distinctively non-spider-like NFR stimuli such as flowers or mushrooms.

In sum, the present study revealed that FR animals were rated higher on fear and elicited a larger LPC over frontal-central regions than did NFR animals. Since the LPC is known to be potentiated when processing motivationally salient stimuli relative to neutral stimuli, enhanced LPC to FR animals suggests that these stimuli are processed more deeply. The finding of larger LPC to FR animals is congruent with visual search literature that suggests FR animals capture attention (e.g., Lipp and Waters 2007). However, individual differences qualified this effect when participants were divided into low fear and high fear groups. Participants in the low fear group showed clear differentiation between FR and NFR animals on subjective ratings of fear and LPC modulation. In contrast, participants in the high fear group did not show the same degree of differentiation between FR and NFR animals in terms of LPC facilitation and reported elevated fear of both NFR and FR animals compared to the low fear group. These findings suggest that enhanced attentional processing of feared-FR animals may extend to other animals that are similar in appearance but which are essentially harmless. The process or mechanism through which this generalisation may occur remains unclear although there is some evidence that preferential attentional processing may facilitate the acquisition of robust fears through associative learning processes. This may have considerable implications in the treatment of simple animal phobia such that fear of snakes or spiders may indicate a more generalized fearfulness of a range of "creepy crawlies".

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