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The power of fear-relevant features: Evidence for generalization of enhanced attentional processing  
and subjective fear in snake- and spider-fearful individuals

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Running Head: Generalization of attentional processing and fear in snake and spider fearful  
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## 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

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 (Jacobi et al., 2004; Gerdes, Uhl & Alpers, 2009). 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 (2002) 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, Fredrickson, Hugdahl & Rimmö, 1976), (b) acquired after a single learning episode (Öhman, Eriksson & Olofsson, 1975), (c) resistant to extinction (Öhman, Erixon & Löfberg, 1975), and (d) irrational and unaffected by cognitive influences (Hugdahl & Öhman, 1977; Lipp & 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 (Öhman, Flykt & Esteves, 2001; Lipp, 2006). 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 & Hackley, 1991). Search

time for a neutral target animal in 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 & Soares, 1994). Similarly, unselected participants showed differential electrodermal responding to conditional stimuli following training with FR stimuli, but not NFR stimuli (Esteves, Dimberg & Öhman, 1994; Flykt, Esteves & Öhman, 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, Mineka & Cook, 1989). A study by Mühlberger, Wiedemann, Herrmann, and Pauli (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 (Öhman, Flykt & Esteves, 2001; Lipp, 2006; Lipp & Waters, 2007) and dot probe (Lipp & 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, Musial, Mohr, Trippe & Miltner, 2005; Kolassa, Musial, Kolassa & Miltner, 2006; Miltner, Trippe, Kireschel, Gutberlet, Hecht & Weiss, 2005; Schienle, Schäfer & Naumann, 2008). 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. Typically, the LPC is potentiated when processing emotionally arousing stimuli relative to neutral stimuli (Schupp, Junghöfer, Weike & Hamm, 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.

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, Schäfer & Naumann, 2008). Investigations into individual differences in the processing of these FR animals between spider phobic participants and controls have consistently found that phobics display larger P300 and/or LPC to spider pictures (Kolassa et al., 2005; Miltner et al., 2005; Schienle, Schäfer & Naumann, 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 present study used ERPs to compare processing of FR animals (snakes and spiders) and appearance-matched NFR control animals in a group of unselected participants who were divided based on 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. Thus, any differences in the processing of FR and NFR animals revealed through examination of ERPs can be more confidently attributed to stimulus “fear relevance” rather than to gross differences in physical appearance or explicit task demands.

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, Uhl & Alpers, 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 other “creepy crawlies” (e.g., arthropods, reptiles or 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.

## 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, Weerts, Hastings, Melamed, & Lang, 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 = .618,  $p = .006$ . 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 beetles, spiders, snakes, worms, cats, dogs, deer, and horses (9 pictures of each species). Pictures were sourced from the internet and resized to 426 x 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 1280 x 1024 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 in an order counterbalanced across participants. Each task consisted of 200 trials. In one task, the participant pressed the response button when the animal presented belonged to a species that has four legs and withheld their response when the animal belonged to a species that does not have four legs. The other task was the opposite – 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 ~1200 ms. Inter-trial intervals varied randomly between 2000 and 2200 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 & Forster, 2003).

#### *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 1000Hz and amplified with a high pass filter of 0.15Hz, and a low pass filter of 100Hz. 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 [ $> 160 \mu\text{V}$ ], 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 30Hz at 24dB per octave. Continuous data files were divided into

1600 ms epochs commencing 100ms prior to stimulus onset and baseline corrected. High and low voltage cut-offs for artefact rejections were set at 100 $\mu$ V and -100 $\mu$ V respectively.

EEG epochs containing correct responses 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 ( $\mu$ V) 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 analysed in a 2 x 2 x 2 x 2 x 5 x 3 (Group x Task x Appearance x Fear relevance x Midline x 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 using Greenhouse-Geisser error values and degrees of freedom to protect against violation of the assumption of sphericity.

## 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 x 2 x 6 (Group x Task x Animal) factorial ANOVA of response accuracy revealed no significant effects or interactions, all  $F$  values < 3, ns.

### *Rated Fear*

Fear, pleasantness, and arousal ratings of the four animal categories of interest (worm, snake, spider and beetle) were subjected to separate 2 x 2 x 2 (Group x Appearance x Fear relevance) repeated-measures ANOVAs. The analysis of the fear ratings yielded a main effect for Fear relevance,  $F(1, 14) = 56.041, p < .001, \eta_p^2 = .800$ , and Group,  $F(1, 14) = 60.063, p = .002, \eta_p^2 = .523$ . Of particular interest was the Fear relevance x Group interaction,  $F(1, 14) = 6.918, p = .020, \eta_p^2 = .331$ . The interaction is illustrated in Figure 1 (upper panel), whereby both groups rated FR stimuli as more fear evoking than NFR stimuli [low fear group,  $t(14) = 10.113, p < .05$ , and high fear group,  $t(14) = 4.854, p < .05$ ]. Fear-relevant animals were rated as more feared by the high fear

group than the low fear group,  $t(14) = 3.641, p < .05$ . Non-fear-relevant animals were also rated as more feared by the high fear group than the low fear group,  $t(14) = 8.900, p < .05$ . The interaction between Fear and Group was revealed as the absence of a significant difference between the fear rating of NFR animals in the high fear group and FR animals in the low fear group,  $t(14) < 1.3, ns$ , whereas high fear participants rated FR animals as significantly more fear eliciting than low fear participants rated NFR animals,  $t(14) = 13.754, p < .05$ .

To check for potential between-group differences in fear of animals generally, the fear ratings obtained for the “background” animal categories (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 significant effects or interactions were obtained, all  $F$  values  $< 2.7, ns$ .

#### *Rated Pleasantness*

Pleasantness ratings of worms, snakes, beetles and spiders are presented in the middle panel of Figure 1. Main effects for Appearance,  $F(1, 14) = 19.176, p = .001, \eta_p^2 = .578$ , and Fear relevance,  $F(1, 14) = 9.054, p = .009, \eta_p^2 = .393$ , were subsumed by a Appearance x Fear relevance interaction,  $F(1, 14) = 5.305, p = .037, \eta_p^2 = .275$ . Beetles were rated as more pleasant than the other three species: worms [ $t(14) = 7.455, p < .05$ ], spiders [ $t(14) = 7.813, p < .05$ ], and snakes [ $t(14) = 10.653, p < .05$ ]. Snakes were rated as less pleasant than worms [ $t(14) = 3.199, p < .05$ ] and snakes and spiders were rated as equally unpleasant [ $t(14) < 2.9, ns$ ].

#### *Rated Arousal*

Arousal ratings of the four species are presented in the lower panel of Figure 1. Fear-relevant stimuli were rated more arousing than NFR stimuli. Inspection of the figure 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,  $F(1, 14)$

= 24.307,  $p < .001$ ,  $\eta_p^2 = .635$ , and Appearance,  $F(1, 14) = 9.662$ ,  $p = .008$ ,  $\eta_p^2 = .408$ . No other effects or interactions were significant,  $p$  values  $> .05$ , *ns*.

#### *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 (Figure 2, upper panel), CZ (Figure 2, middle panel) and PZ (Figure 2, lower panel). The LPC was significantly modulated by fear relevance, specifically, LPC mean amplitude was potentiated in response to FR animals,  $F(1, 15) = 5.178$ ,  $p = .038$ ,  $\eta_p^2 = .257$ . LPC mean amplitude also varied across Midline,  $F(4, 12) = 9.422$ ,  $p = .001$ ,  $\eta_p^2 = .758$ , and Coronal sites,  $F(2, 14) = 4.743$ ,  $p = .027$ ,  $\eta_p^2 = .404$ , such that amplitude was larger parietally than frontally (see Figure 2) and was largest over the midline than the right or left hemisphere. Of particular interest was a significant Group x Fear relevance interaction,  $F(1, 15) = 4.741$ ,  $p = .046$ ,  $\eta_p^2 = .240$ . As illustrated in Figure 3, LPC was larger to FR animals than to NFR animals only in the low fear group,  $t(15) = 4.514$ ,  $p < .05$ . LPC mean amplitude shown by participants in the high fear group was similar in response to FR and NFR animals,  $t(15) < 1$ , *ns*. This lack of difference in the high fear group to pictures of FR and NFR animals appears to be driven by enhanced LPC to NFR animals which was significantly larger in the high fear group than in the low fear group,  $t(15) = 4.886$ ,  $p < .05$  and does not reflect on overall electro-cortical responding since mean amplitude of the LPC to FR animals did not differ between groups,  $t(15) < 1$ , *ns*.

#### Discussion

Behavioural and electro-cortical responses to FR animals and appearance-matched NFR animals were investigated in the present study using subjective rating scales and event-related potential methodology. Whereas previous studies have frequently used stimuli such as flowers and mushrooms as NFR controls (but see Carretié, Hincosa, López-Martín, Albert, Tapia & Pozo, 2009; Lipp & 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 attentional and evaluative processing of FR and NFR animals.

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. Interestingly, analysis of participants’ rated fear of other animals (dogs, cats, horses and deer) did not reveal between group effects. Taken together, these findings are in accord with a recent study by Gerdes, Uhl and Alpers (2009) which found spider phobics rated not only spiders, but also other arthropods as more feared than did controls. 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.

Based on previous literature we focused our attention on the late positive complex (LPC) of the ERP waveform. The present results show on the one hand that participants who reported lower levels of snake and spider fear clearly differentiated between the FR and NFR animals on an electro-cortical level. On the other hand, participants who reported relatively higher levels of snake and spider fear failed to show such a differentiation. Specifically, the low fear group showed enhanced LPC to FR animals relative to NFR control animals. 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. This pattern of results 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, Trippe, Krieschel, Gutberlet, Hecht & Weiss, 2005; Schupp, Cuthbert, Bradley, Cacioppo, Ito & Lang, 2000; Schupp, Junghöfer, Weike & Hamm, 2004; Schienle, Schäfer & Naumann, 2008). It is also consistent with research that demonstrated the propensity for FR stimuli to capture attention even in unselected participants (Öhman, Flykt & Esteves, 2001; Lipp, 2006; Lipp & Waters, 2007).

Of particular note was the observation that participants in the high fear group showed undifferentiated LPC mean amplitudes to the FR and NFR animals. Although LPC amplitudes to the snakes and spiders were comparable to those observed in the low fear group, LPC amplitudes to the worms and beetles were significantly larger than in the low fear group. This result suggests that participants who reported higher levels of snake and spider fear engaged in deeper attentional processing of both the FR stimuli and the similar-in-appearance NFR controls. However, it may be that high fear participants process *all* animal stimuli more deeply. In order to exclude this possibility, we analysed the LPC mean amplitudes to the four categories of four-legged 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 and high fear participants processed animal pictures: a between-group effect was not found, nor were any interactions involving the group factor significant<sup>1</sup>.

A second interpretation to consider is that participants with higher snake and spider fear may have a tendency to misinterpret animals that are similar in appearance to feared-FR animals as

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<sup>1</sup> The LPC mean amplitudes to the “background” animals (i.e., dogs, cats, horses and deer) were also analysed in the 2 x 2 x 2 x 2 x 5 x 3 (Group x Task x Appearance x Fear relevance x Midline x Coronal) mixed model ANOVA. The analysis revealed no significant main effects or interactions involving the between-group factor (high vs low fear), all *p* values > .1, *ns*.

snake- or spider-like and therefore, potentially threatening. Drawing on findings from the social phobia literature, Kolassa, Buchmann, Lauche, Kolassa, Partchev, Miltner, and Musial (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. Spider phobic participants were asked to judge whether stimuli were more similar to a spider or a flower as they watched morphed pictorial stimuli gradually transform from a schematic flower into a schematic spider. In addition to the behavioural data, ERPs during stimulus presentations were analysed. The spider phobics showed an interpretative bias on the behavioural level however, 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.

An alternative explanation is that the lack of LPC differentiation between the FR and NFR animals observed in the high fear group reflects on a generalization of motivated attentional processing to NFR animals that share certain features with, and 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. Individuals who are especially fearful of snakes and spiders may be more inclined to attend to other stimuli that share at least some salient physical characteristic(s) with the feared-FR stimuli thereby increasing the relevance of these NFR stimuli and the degree of attentional processing allocated to them. It has



previously been suggested that preferential attentional processing of FR stimuli (Öhman & Mineka, 2001) and NFR stimuli (Purkis & Lipp, 2009) may facilitate fear learning mechanisms which increase fear responding to such stimuli. Thus, this explanation of the LPC results may also help to explain why participants in the high fear group were more afraid of worms and beetles than participants in the low fear group (see also Gerdes, Uhl & Alpers, 2009).

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 & 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, especially in terms of LPC facilitation. These findings suggest that fear and enhanced attentional processing of feared-FR animals may generalize to other animals that are similar in appearance but not considered evolutionarily fear-relevant. Future research can investigate the mechanisms through which this generalisation may occur and the implications for the treatment of simple animal phobia.

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## List of Figures

*Figure 1.* Post-experiment ratings (*Ms* and *SE*) 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.

*Figure 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).

*Figure 3.* Late Positive Complex (LPC) mean amplitude (*+SE*) recorded at Fz to worm, snake, beetle and spider stimuli (collapsed across tasks) by participants assigned to the low fear or high fear group.