

## Tracking fear in snake and spider fearful participants during visual search: A multi-response domain study

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In visual search tasks snake or spider fearful participants showed shorter reaction times (RTs) to respond to their feared animal (e.g., snake) than to the nonfeared animal (i.e., spider) (Öhman, Flykt, & Esteves, 2001). Here, we used this paradigm with heart rate (HR), RTs, and event-related potential (ERP) measures, to investigate the nature of the responses to the feared animal, a nonfeared (but fear-relevant) animal, and fear-irrelevant target stimuli with snake fearful, spider fearful, and nonfearful participants. Fearful participants showed shorter RTs and evoked larger amplitudes on a late positive potential (LPP; 500–700 ms) for their feared compared to the nonfeared and the fear-irrelevant targets. No relevant significant differences were found on early ERP components and HR measures. These findings do not support an involvement of early information processing in the detection of the feared animal in fearful participants, they favour instead a more elaborated analysis of these complex stimuli to achieve the detection.

When snake or spider fearful participants were exposed to pictures of their feared animal (e.g., a spider), a nonfeared (but fear-relevant) animal (e.g., a snake), and fear-irrelevant stimuli (e.g., a flower), they showed larger skin conductance responses (SCRs) to the exposure of their feared animal than for the other two types of stimuli (Öhman & Soares, 1994). A comparable

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phenomenon occurred when these biological stimuli were backwardly masked to prevent conscious awareness of the picture content, a result that has been interpreted as evidence for preattentive processing of feared stimuli, a processing that precedes and directs attention by focusing resources at the crucial stimuli when awareness occurs (see Logan, 1992). Öhman (1993; Öhman & Wiens, 2004) postulated that such processes occur for biologically relevant threats and evoke faster responses for these particular visual stimuli compared to other visual stimuli.

The idea that feared and fear-relevant animals would direct attention has been also supported by the results from a series of visual search experiments by Öhman, Flykt, and Esteves (2001) in which randomly selected participants were instructed to indicate the presence or absence of a target stimulus in  $2 \times 2$  and  $3 \times 3$  matrices of objects (i.e., grid pattern). Reaction times (RTs) for a fear-relevant target stimulus among fear-irrelevant distractor stimuli were shorter than in the opposite situation (i.e., a fear-irrelevant target stimulus among fear-relevant distractors). In the third experiment of this series, individuals were selected based on their score on a questionnaire that evaluated their fear for snakes and spiders (see Klorman, Weerts, Hastings, Melamed, & Lang, 1974). Fearful participants had shorter reaction times (RTs) in response to their feared target animal than to the nonfeared (but fear-relevant) one. With the exception of the feared target animal, fearful participants did not differ in their RTs from the low/no fear control group.

To disentangle the effects of target from distractors, two follow-up studies (Flykt, 2005, 2006) were designed using all possible combinations of targets and distractors within random samples of participants. The results suggest an involvement of controlled processes in this paradigm—an initial effect of the target stimulus on heart rate (HR) measure followed by an effect of the distractors was shown (Flykt, 2005). Furthermore, when participants were required to withhold their responses for a certain time after the matrix search array off-set, the results indicated that reaction times (RTs) are a function of the number of fear-relevant pictures in the search arrays, the more fear-relevant pictures the shorter RTs (Flykt, 2006), reflecting a preparedness to act on potential threats.

The findings based on the visual search experiments by Flykt (2005, 2006) suggest an initial effect of the target followed by effects of the distractors and support the *Perceptual Load Theory* introduced by Lavie (1995, 2005; Lavie & Tsai, 1994). Lavie postulated that when a task required a large amount of resources, no additional resources are available for perceptual-parallel processing. When, however, attentional demands are low, or working memory load is requested, stimuli besides those in the focus of attention would influence information processing (see Lavie, 2005). In the visual search task framework, this theoretical position suggests that a search task that requires a lot of resources will not be affected by distractor stimuli, or

even by aspects of the target stimulus, until the controlled processing of the search has been achieved.

In a modified replication and extension of the Öhman et al. (2001) study, Lipp, Derakshan, Waters, and Logies (2004) have also found shorter RTs, among randomly selected participants, when snake and spider stimuli were exchanged for nonfear-relevant animals, such as horses and domestic cats. This finding suggests that animals per se may have more response driving properties than flowers and mushrooms. From an evolutionary point of view it would be functional that objects that could potentially approach or advance away from the observer, independently of their fear-relevance, should elicit more activation, as they might necessitate a reaction.

When required to search for a mushroom among flowers, spider fearful participants showed an increase in RTs when one of the flowers was replaced by a picture of a spider (Miltner, Krieschel, Hecht, Trippe, & Weiss, 2004). This increase in RTs could result from an attentional capture by the spider picture. However, an alternative or complementary explanation of such attentional bias would result from a problem in attentional disengagement occurring after the detection of the feared animal. Problems to disengage attention from threat have been proposed to be a central aspect of attentional biases toward threat (Fox, Russo, Bowles, & Dutton 2001; Fox, Russo, & Dutton, 2002). Consequently, the idea that fear-relevant (but nonfeared) animals would have response driving properties different than those of other animals in visual search tasks can be questioned based on the results from Lipp et al. (2004). Nevertheless, when the feared animal is a target in visual search tasks such as those used by Öhman, et al. (2001), it would appear beyond doubt that fear for snakes or spiders decrease RTs for the feared animal.

If fear for animals has response driving properties, whether genetically predisposed or acquired, these properties could be based either on parallel-perceptual processing or on more elaborate processing that require a certain amount of resources to be available, as would be suggested by the *Perceptual Load Theory* (Lavie, 1995, 2005). In the former case, the feared animal would be processed independently of the perceptual load of the task and effects should be shown in the PI/N1 complex of event related potentials (ERPs), two electrophysiological components modulated by spatial selective attention (see e.g., Luck, Woodman, & Vogel, 2000). Alternatively, if perceptual load would block responses to feared animals, no differential PI/N1 responses should be expected.

Consequently, event-related potentials (ERPs) represent a suitable technique to investigate the processes that precede the behavioural outcome from which attentional biases are inferred. Validly cued targets evoke larger amplitude for the PI (90–130 ms) and N1 (150–200 ms) ERP components over the extrastriate occipital area for attended stimuli as compared to

unattended stimuli (e.g., Mangun & Hillyard, 1991). Vogel and Luck (2000) suggested that the N1 could represent a discrimination process. Thus, the investigation of such components allows the identification of the earliest time point at which attention could play a role in the emotional processing of visual images. Another robust finding in the framework of ERP in processing of emotional picture content relies on an increased response, occurring between 400 ms and 700 ms over the centroparietal electrodes, for pleasant and unpleasant stimuli as compared with neutral stimuli; the late positive potential (LPP), relating to the intensity of the emotional stimulation (Cacioppo & Berntson, 1994; Crites, Berntson, & Coles, 1993; Cacioppo, Crites, & Gardner, 1996; Cacioppo, Crites, Gardner, & Berntson, 1994; Cacioppo, Diedrich, Naumann, Maier, & Bartussek, 1997; Schupp et al., 2000). It has been demonstrated that the exposure to negative pictures evokes a larger positive component over the centroparietal regions than positive pictures at about 500 ms (Ito & Cacioppo, 2000; Dolcos & Cabeza, 2002; Ito, Larsen, Smith, & Cacioppo, 1998). According to Schupp et al. (2004) the existing results on LPP are consistent with the hypothesis that it reflects an elaborated perceptual processing. Ito and Cacioppo (2000) proposed that LPP reflects a competition for processing resources. However, whether the LPP component is modulated by the fear that a stimulus elicits remains to be clarified.

In the present study participants were selected based on their responses on reduced versions of the spider and snake fear questionnaires (Klorman et al., 1974) to form a snake fearful group, a spider fearful group, and a group, not fearful of spiders or snakes (the nonfearful group). In both experiments participants were required to detect whether a target was present in the matrix search array or not. In Experiment 1, participants were engaged in a training phase and had to search for a target stimulus without responding. During this phase, signals were acquired for the HR measure. In the second phase, they were required to indicate their responses by pressing one out of two buttons. In Experiment 2 (in which the signals for the ERPs were acquired), participants were instructed to search for a target on all trials, but to respond uniquely when the target stimulus was followed by a question mark, which randomly occurred after the presentation of the matrix search array. We hypothesised that a feared target in comparison with other targets would result in: (1) a different HR response pattern; (2) shorter RTs; and (3) would result in modulated patterns of brain activations. Such activations would be shown in the P1/N1 complex if pre-attentive processing directed attention to the feared target. In the absence of preattentive processing, the differential responses would not occur prior to the detection of the target stimulus.

## EXPERIMENT 1

## Method

*Participants.* These were recruited from a sample of 250 first semester students in psychology at University of Geneva who had completed short versions (see Carlsson et al., 2004) of the snake (20 items) and spider (18 items) questionnaires of Klorman, Weerts, Hastings, Melamed, and Lang (1974). The use of only some items of the questionnaires was based on an item analysis of the responses on the 30 Snake items and the 31 Spider items by the approximately 130 medical students who had filled in the original questionnaire in the Öhman et al. (2001) study (unpublished data). All participants were French speakers and the questionnaires were translated and completed in French.

The nonfearful group consisted of nine participants (three males) all right-handed, with an average age of 24 years ( $SD = 5$ , range 20–35 years). Their mean spider score was 0.3 ( $SD = 0.5$ , range 0–1) and their mean snake score was 0.7 ( $SD = 0.5$ , range 0–1). The spider fearful group consisted of nine participants (one male) all right-handed, with an average age of 21 years ( $SD = 2$ , range 19–24). Their mean spider score was 12.2 ( $SD = 1.6$ , range 10–15) and their mean snake score was 1.4 ( $SD = 1.1$ , range 0–3). The snake fearful group consisted of nine participants (all female) four right-handed, with an average age of 23 years ( $SD = 5$ , range 19–33). Their mean spider score was 1.4 ( $SD = 0.5$ , range 1–2) and their mean snake score was 15 ( $SD = 2.8$ , range 11–19).

*Stimulus materials.* The same picture materials presented in 3 x 3 items (i.e., matrix) search arrays as in the Öhman, et al. (2001) study were adopted. Each combination of a snake among flowers, a snake among mushrooms, a spider among flowers, a spider among mushrooms, a flower among mushrooms, and a mushroom among flowers were presented in nine different search array constellations. Aside from these 54 search arrays, an additional 54 arrays with the target (the remaining combinations of target and distractors) and 36 arrays without the target were used as filler trials.

*Apparatus.* The search arrays were presented on a 17 inch. (43 cm) screen. The size of the search arrays was approximately 23.5 cm x 15.5 cm and the viewing distance was approximately 1 metre. The Experimental Run Time System (ERTS; see Dutta, 1995) was used for the stimulus generation and collection of RTs with the EXKEY-logic and response pad. The interstimulus intervals (ISIs) varied randomly between 3 s and 4 s and in the second-phase the RT was added to the ISIs (maximum 2000 ms). BioPac system (see e.g., Frazier, Strauss, & Steinhauer, 2004) MP100TEL with the

dedicated software, AcqKnowledge 3.5 (see e.g., Leong, Mann, Wallymahmed, MacFarlane, & Wilding, 2001), was used for recording the ECG signal and a signal indicating the stimulus presentation. The ECG signal was sampled at 500 Hz.

*Procedure.* These were informed that the task was a pretest for an ERP experiment, in which they were encouraged to participate in later. The experiment comprised two phases. During the first phase, which was presented as a training period, participants were instructed that they had to perform the search task, but not to respond. In the second phase, participants were instructed to respond by pressing a button if the target was present or another button if the target was absent. Participants were required to press a button with their nondominant hand if all the items in the search array belonged to one of the categories spiders, snakes, flowers, or mushrooms. If one picture in the display belonged to a different category than the rest of the pictures a button had to be pressed with their dominant hand. Before starting the experiment ECG electrodes were attached (the ground to the neck, the reference electrode to the right side about 10 cm below the armpit, and the active electrode at about the same position on the left side).

*Design.* As the focus of interest was the differences between feared, nonfeared (but fear-relevant), and fear-irrelevant targets and to reduce the complexity of the results in terms of the ERP experiment only, these three different conditions were used for the analysis. The conditions were: (1) a snake among flowers or mushrooms; (2) a spider among flowers or mushrooms; and (3) a flower among mushrooms or a mushroom among flowers. The design for the ANOVA had group (Snake fearful, Spider fearful, Nonfearful) as between variable and target as within variable (Snake, Spider, Fear-irrelevant).

*Data treatment.* Only the heart rate data obtained during the first (i.e., “the training”) phase were used for the analysis. The peaks of the R-waves were used for the calculation of interbeat intervals (IBIs). After visual inspection, artifacts were removed on all trials. No attempts to correct for respiratory responses were made. The baseline consisted of the two entire IBIs before stimulus onset. For the analysis of RT data only correct responses were used. Violation of the sphericity assumption of repeated measure ANOVA was corrected by the use of Greenhouse-Geisser to adjust all probabilities ( $p$ ). The original degrees of freedom were, however, used for readability of the results. When  $t$ -tests were used Cohen’s (1988)  $d$  was reported as an indicator of the effect size.

## Results

No significant differences were found for HR measures (see Table 1 for means and standard deviations). The ANOVA for the RTs showed longer RTs for fear-irrelevant targets (1040 ms) than snake or spider targets (both 817 ms), as shown by a main effect of target,  $F(2, 24) = 52.77$ ,  $p < .01$ ,  $MSE = 9339$ ,  $\eta^2 = .69$ . The RTs were shorter for spider than for snake targets in the spider fearful group, and shorter for snake than spider targets in the snake fearful group, for the nonfearful group the mean RT was shorter for spider targets than snake targets. This was shown by the interaction effect Target  $\times$  Group,  $F(4, 24) = 2.94$ ,  $p = .04$ ,  $MSE = 9339$ ,  $\eta^2 = .20$  and a priori  $t$ -tests. Spider target vs. snake target: Spider fearful (one-tailed);  $t(8) = 4.25$ ,  $p < .01$ ,  $d = 0.83$ , Snake fearful (one-tailed);  $t(8) = -2.11$ ,  $p = .04$ ,  $d = 1.13$ , and Nonfearful;  $t(8) = 2.83$ ,  $p = .03$ ,  $d = 0.61$  (see Figure 1).

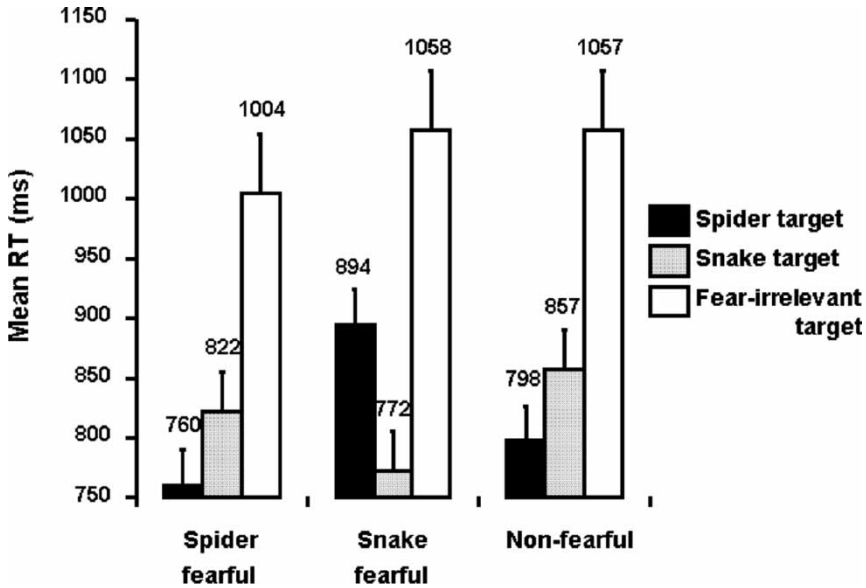
## Discussion

No significant difference on HR measures was found between the different conditions. The fearful groups showed shorter RTs for the feared target animal than the other animal or the fear-irrelevant targets, replicating the Öhman et al. (2001, experiment 3) results. The nonfearful group showed shorter RTs to spider targets than snake targets.

The results of a previous visual search study by the first author (Flykt, 2005) revealed less heart rate deceleration to fear-relevant than fear-irrelevant targets. Thus, at first sight, the absence of an effect in HR measures in the present study may appear odd. It could, however, be explained by a difference in the population under investigation—while the previous study (Flykt, 2005) was conducted using randomly selected participants, the current study involved participants who were selected on the basis of a questionnaire relating to their fear of the investigated

TABLE 1  
Means (and standard deviations) of heart rate (HR) change scores  
(groups in columns and targets in rows)

	<i>HR change scores</i>		
	<i>Spider fearful</i>	<i>Snake fearful</i>	<i>Non fearful</i>
Spider target			
Mean (SD)	-1.00 (1.54)	-1.32 (2.73)	-0.88 (1.53)
Snake target			
Mean (SD)	-1.41 (2.59)	-0.72 (1.92)	-1.54 (0.94)
Fear-irrelevant target			
Mean (SD)	-1.70 (2.37)	-0.48 (1.28)	-0.70 (1.13)



**Figure 1.** Mean reaction times (RTs) in ms. Displayed results are based on the condition "A target spider among flowers or mushrooms" (black bars), the conditions "A target snake among flowers or mushrooms" (grey bars), and the condition "A flower among mushrooms or a mushroom among flowers" (white bars) for the three groups, Snake fearful ( $n=9$ ), Spider fearful ( $n=9$ ) and Nonfearful ( $n=9$ ). Vertical bars report the mean standard errors, the numbers displayed above report the mean RT values (ms).

biological stimuli. The possibility of being exposed to their feared animal could have resulted in anticipatory strategies that modulated the nature of the responses involved in the detection of the feared animal or the detection of another target. This anticipatory effect could then have interfered with a spontaneous evoked heart rate changes due to the target detection.

As expected, fear-irrelevant targets resulted in longer RTs than the other targets. Spider and snake fearful participants showed shorter RTs for their respective feared target stimulus, compared to the other target stimuli. However, shorter RTs to spider than snake targets in the nonfearful participants were observed. This difference in RTs could reflect a general preferential processing of spider than snake targets, which could be associated with faster central nervous processing for spider than snake targets. To address this question and to investigate whether, where and when feared animals are differentially processed with respect to a nonfeared (but fear-relevant) animal, we adopted the visual search paradigm with a simultaneous recording of the electroencephalographical activity.



## EXPERIMENT 2

## Method

*Participants.* The same participants as in Experiment 1 took part in this experiment.

*Stimulus materials.* The same stimuli as in Experiment 1 were used in this experiment.

*Procedure.* Participants were seated in a dimly illuminated and sound attenuated electrically shielded room, facing a colour-video monitor at a distance of 120 cm. A fixation cross was continuously visible in the centre of the screen. The total number of matrix search arrays presented to each participant was 1872. Each image subtended a visual angle of  $6.68^\circ$  by  $4.39^\circ$ . Of these 1872 search arrays, 117 were presented for each combination of target and distractors (e.g., a snake among flowers, a spider among mushrooms). Each matrix search array was presented for 1500 ms, with an ISI randomised between 1500 ms and 2500 ms between the different presentations. Participants were instructed to search for a deviant picture among a congruous category of pictures. On 272 of the trials a question mark followed the matrix search array exposure. Only on these trials the participants were required to respond by differential key pressing dependent on whether a picture from a deviant category was present or not. These verification trials were used to keep a high level of attention and were excluded for the analysis. The background colour of the monitor was black.

*ERP recording and averaging.* The EEG was recorded from 64 silver/silver chloride electrodes. Of these, 62 were embedded in an elasticised cap montage (QuickCap, NeuroScan Inc., USA), arranged according to the International 10–20 system. An electrode was placed on the tip of the nose and used as a common reference for all the cap electrodes. Ocular artifacts were recorded and monitored by using bipolar electrodes on the outer canthus of each eye, and vertical EOG was recorded from electrodes placed above and below the eye. Vertical blinks were corrected off-line by an automatic algorithm (Scan 4.2, Neuroscan Inc., USA). The sampling rate was 1000 Hz (band pass 0.15–70 Hz). Electrodes impedances were kept under 5 k $\Omega$ . EEG epochs extended from 200 ms before to 1500 ms after stimulus onset. Data were baseline corrected to the first 200 ms of the epoch. Epochs were carefully scanned, and the epochs presenting remaining artifacts were rejected before averaging the individual evoked potentials. Finally, a low-pass filter of 30 Hz was applied and the data were rescaled across the average reference.

*ERP analysis.* To investigate the emotional effect of the stimuli, for the three groups of subjects peak amplitudes and peak latencies were computed for the matrix search arrays with a target stimulus (snake, spider, and fear-irrelevant) among fear-irrelevant stimuli (mushrooms or flowers) in three time windows: between 90 ms and 150 ms (PI), 120 ms and 190 ms (NI) and, after visual inspection, 500 ms and 700 ms poststimulus onset (LPP). These values were calculated with an automatic algorithm for each selected electrode and each condition at a single latency per component and per each subject. The electrodes of interest for the PI/NI complex were P3, P03 in the parietooccipital area of the left hemisphere, and P4, P04 for the right hemisphere. For the LPP component three Regions Of Interest (ROI) of nine electrodes each were defined in the central part of the scalp. The left ROI was defined by pooling and average the activity on FT7, FC5, FC3, T7, C5, C3, TP7, CP5, CP3 electrodes; for the central ROI on the FC1, FCZ, FC2, CI, CZ, C2, CP1, CPZ, CP2 electrodes; and finally for the right ROI on the FT8, FC6, FC4, T8, C6, C4, TP8, CP6, CP4.

*Design.* Analyses of variance (ANOVAs) with group (Snake fearful, Spider fearful, Nonfearful) as a between-subject factor and target (Snake, Spider, Fear-irrelevant), Hemisphere (Left, Right for the PI/NI complex-Left, Central, and Right for the LPP) and electrodes (for the PI/NI complex) as within-participant variables were conducted for peak amplitudes and latency. Violation of the sphericity assumption with a repeated-measures ANOVA was corrected by the use of Greenhouse-Geisser to adjust all probabilities ( $p$ ). The original degrees of freedom were, however, used for clarification of the results.

## Results

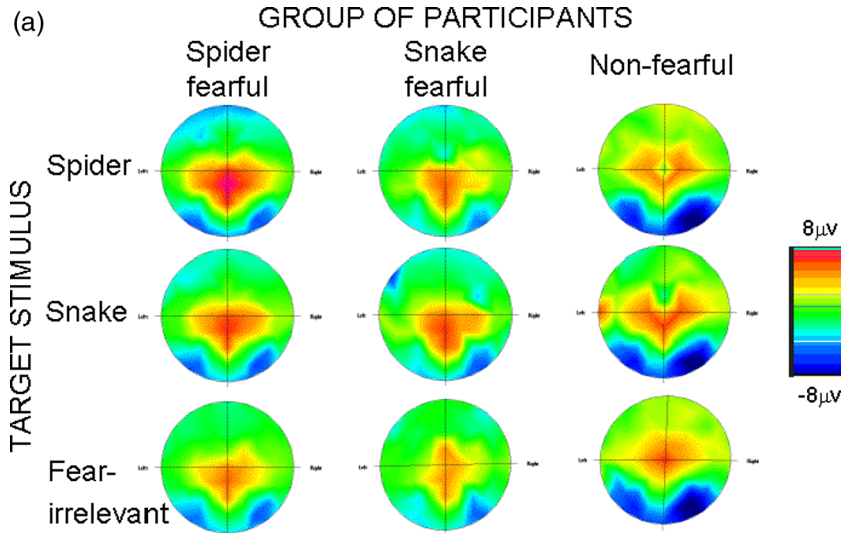
For the PI-NI complex: The PI amplitude was larger over the P- ( $6.86 \mu\text{V}$ ) than PO-electrodes ( $5.87 \mu\text{V}$ ),  $F(1, 24) = 12.11$ ,  $p < .01$ ,  $MSE = 6.52$ ,  $\eta^2 = .34$ . The PI peak latency occurred later for the P- (114 ms) than the PO-electrodes (110 ms),  $F(1, 24) = 4.48$ ,  $p < .05$ ,  $MSE = 244.90$ ,  $\eta^2 = .16$ . The latency for the PI was shorter for the right (111 ms) than the left hemisphere (113 ms),  $F(1, 24) = 6.05$ ,  $p = .03$ ,  $MSE = 95.37$ ,  $\eta^2 = .20$ . There was also a Target  $\times$  Electrode  $\times$  Hemisphere  $\times$  Group interaction effect,  $F(4, 48) = 3.23$ ,  $p = .04$ ,  $MSE = 29.69$ ,  $\eta^2 = .21$ . No reasonable interpretation could be made for this interaction, or for the Target  $\times$  Electrode  $\times$  Hemisphere  $\times$  Group interaction effect for the NI amplitude,  $F(4, 48) = 2.63$ ,  $p < .05$ ,  $MSE = 0.22$ ,  $\eta^2 = .18$ . The NI latency for the PO-electrodes (155 ms) was shorter than for the P-electrodes (161 ms),  $F(1, 24) = 23.26$ ,  $p < .01$ ,  $MSE = 146.43$ ,  $\eta^2 = .49$ . The latency for the right hemisphere (156 ms) was shorter than for the left hemisphere (160 ms),  $F(1, 24) = 5.34$ ,  $p = .04$ ,  $MSE = 197.45$ ,  $\eta^2 = .18$ .

A positive component between 500 ms and 700 ms from stimulus onset (LPP, see Table 2 and Figure 2a and 2b) showed larger amplitudes for spider targets (4.42  $\mu\text{V}$ ) than fear-irrelevant targets (3.51  $\mu\text{V}$ ),  $F(2, 48) = 3.82$ ,  $p = .03$ ,  $MSE = 4.38$ ,  $\eta^2 = .14$ , and Bonferroni corrected pairwise comparisons. In the spider fearful group spider targets resulted in larger amplitude (5.92  $\mu\text{V}$ ) than snake and fear-irrelevant targets (3.95 and 3.72  $\mu\text{V}$ , respectively), and in the snake fearful group the snake target resulted in a larger amplitude (4.74  $\mu\text{V}$ ) than spider and fear-irrelevant targets (3.61 and 3.09  $\mu\text{V}$ , respectively). In the non-fearful group there was no difference between the three different targets. This was shown by an interaction effect between target and group,  $F(4, 48) = 4.84$ ,  $p < .01$ ,  $MSE = 4.38$ ,  $\eta^2 = .29$ , and a priori  $t$ -tests. Spider target vs. snake target: Spider fearful (one-tailed);  $t(8) = -2.70$ ,  $p = .02$ ,  $d = 0.93$ , Snake fearful (one-tailed);  $t(8) = 3.09$ ,  $p < .01$ ,  $d = 0.66$ , and Nonfearful;  $t(8) = -0.40$ ,  $p > .69$  (see Figure 2). The central ROI had a higher maximum amplitude (4.26  $\mu\text{V}$ ) than the left (3.73  $\mu\text{V}$ ) and the right (3.80  $\mu\text{V}$ ) ROIs,  $F(2, 48) = 13.57$ ,  $p < .01$ ,  $MSE = 0.56$ ,  $\eta^2 = .36$ .

The ANOVA for the latency of the maximum amplitude of the LPP showed a shorter latency for the spider targets (590 ms) than for the fear-irrelevant targets (604 ms), as shown by a main effect of target,  $F(2, 48) = 3.48$ ,  $p < .01$ ,  $MSE = 1253.31$ ,  $\eta^2 = .13$ , and Bonferroni corrected pairwise comparisons. The latency of the maximal LPP amplitude was shorter for the left ROI for the spider targets (586 ms) than for the central (593 ms) and the right (592 ms) ROIs, as shown by an interaction between target and ROI,  $F(2, 96) = 2.78$ ,  $p < .05$ ,  $MSE = 44.61$ ,  $\eta^2 = .10$ , and corrected pairwise comparisons.

TABLE 2  
Mean amplitudes ( $\mu\text{V}$ ) and latencies (ms) values for the late positive potential (LPP) component (groups in columns and targets in rows)

	<i>LPP (500–700 ms)</i>		
	<i>Spider fearful</i>	<i>Snake fearful</i>	<i>Non fearful</i>
Spider target			
Amplitude ( $\mu\text{V}$ )	5.92	3.61	3.72
Latency (ms)	588	591	592
Snake target			
Amplitude ( $\mu\text{V}$ )	3.95	4.74	3.46
Latency (ms)	602	591	607
Fear-irrelevant target			
Amplitude ( $\mu\text{V}$ )	3.72	3.09	3.72
Latency (ms)	610	607	596

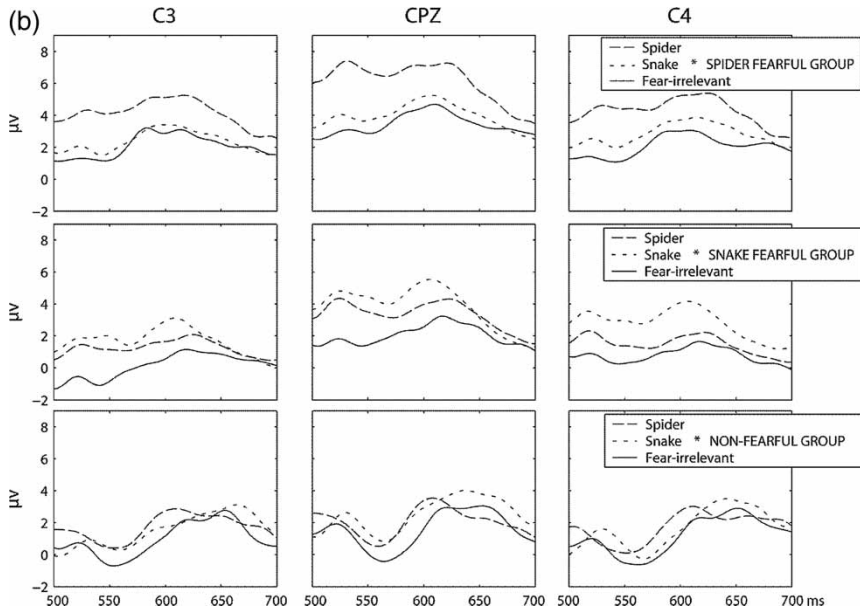


**Figure 2a.** Event-related potential (ERP) maps for the time window 500–700 ms late positive potential (LPP) after stimuli onsets rescaled across the average reference. All maps are viewed from the top, with the nose up and the left ear to the left (red = positive in activity in relation to the reference, white = no difference in activity in relation to the reference, and blue = decrease in activity in relation to the reference) for the three groups Spider fearful ( $n = 9$ ), Snake fearful ( $n = 9$ ), and Nonfearful ( $n = 9$ ). The upper row shows the activity over the scalp for the condition: “A target spider among flowers or mushrooms”. The middle row shows the activity over the scalp for the condition: “A target snake among flowers or mushrooms”. The lower row shows the activity over the scalp for the condition: “A target flower among mushrooms or a mushroom target among flowers”. [View the Figure online to see a colour version.]

## Discussion

The ERP analyses comparing the PI/N1 component for the feared and the not feared target animals or the fear-irrelevant targets did not reveal any difference in terms of amplitude or latency. However, the LPP component showed a larger amplitude for the feared animal than the nonfeared animal and the fear-irrelevant targets.

The N1 was expected to evoke larger amplitudes for attended stimuli than not attended stimuli (Mangun & Hillyard, 1991), representing a discrimination processing (Vogel & Luck, 2000). The absence of any differential responding at the PI/N1 in the present experiment indicates that no early differentiation between the different target stimuli took part. Our data indicate instead a more elaborated perceptual processing (Schupp et al., 2004) or a competition for resources (Ito & Cacioppo, 2000) by showing more enhanced amplitude of the late positive potential (LPP; 500–700 ms) for the feared stimulus than for the other animal (and the fear-irrelevant)



**Figure 2b.** Grand-averaged event-related potential (ERP) waveforms rescaled across the average reference at central electrodes (C3, CPZ, C4) in response to Spider, Snake, and Neutral (flowers and mushrooms) detections, within spider fearful (top), snake fearful (middle) and Nonfearful participants (bottom). Positive values are up. Note the occurrence of an enhanced LPP in fearful participants detecting their respective feared animal, and a similar response for all the visual categories in the Nonfearful participants.

targets. Such modulation for the LPP component might reflect a difference in the arousal evoked by the feared animal target as compared to the other targets. This arousal would be considered an integrated part of a fear response (see e.g., Fanselow & Lester, 1988; Lang, Bradley, & Cuthbert, 1997) and not as a separate dimension as previously argued by Schupp et al. (2004).

The main effect due to shorter latency of the maximum amplitude of the LPP for spider targets than the fear-irrelevant targets might indicate that spiders in general are faster processed than snakes. This speed difference resonates with the difference in the RTs of the first experiment for the non-fearful participants.

## GENERAL DISCUSSION

Our results are consistent with Öhman et al.'s (2001) findings, as they show shorter RTs to the feared animal in the fearful groups. ERP data from the

same participants added important information to previous findings, by showing enhanced LPP amplitude to feared animal targets compared to the nonfeared (but fear-relevant) animal targets. Early ERP components were shown not sensitive for discriminating between the feared and nonfeared target animals. As a consequence, three important results were established in our study, which we discuss in turn.

First, the larger amplitude of the LPP component observed in fearful participants for the feared animal targets, compared to the nonfeared animal targets, is in line with previous findings showing a more enhanced LPP component for unpleasant than neutral stimuli (Cacioppo & Berntson, 1994; Cacioppo, Crites, Berntson, & Coles, 1993; Cacioppo, Crites, & Gardner, 1996; Diedrich et al., 1997; Cacioppo, Crites, Gardner, & Berntson, 1994). Our pattern of results is also in line with some studies that have shown a modulation of the LPP component for unpleasant compared to pleasant stimuli (e.g., Dolcos & Cabeza, 2002; Ito et al., 1998; Schupp et al., 2004).

By selecting the participants for being fearful of one particular animal (e.g., spider), but not another animal (i.e., snake), an interaction was observed between the feared object and the nature of the fear in the participants, providing the first direct evidence for fear related modulation on the LPP component. The feared animal condition elicited a larger LPP compared to the nonfeared (but fear-relevant) animal condition. Thus, the LPP component might reflect an elaborated perceptual processing (Schupp et al., 2004), or a competition for resources (Ito & Cacioppo, 2000) modulated by participants' fearfulness of the visual stimulus. Such a competition for resources might, with respect to a feared animal, be related to an allocation of processing resources to handle the threat stimulus. From an evolutionary view an efficient handling of the threat with speeded actions would per se be more important than a fast detection of the threat per se (Flykt, 2006).

Second, the absence of an expected difference in the PI/N1 complex between feared and nonfeared target conditions for the fearful groups does not favor an early perceptual-parallel process that would direct attention towards the feared target and result in a faster detection and subsequently shorter RTs to feared target stimuli, as suggested by Öhman et al. (2001). However, such early fear related processing might occur in the amygdala nuclei (see e.g., LeDoux, 1996) rather than in the activity of the extra-striate cortex captured in the PI/N1 complex. The activations arising from the amygdala are not directly recordable with the ERP technique. As a consequence, any conclusion on the involvement of that particular structure of the brain in our experiment would be speculative. Our results can only support an absence of an attentional modulation within the PI/N1 complex. However, an alternative interpretation would rely on the fact that an attentional bias in processing visual information would occur only when the

target has been detected. As demonstrated by previous findings (Flykt, 2005, 2006) and in accordance with the *Perceptual Load Theory* (Lavie, 1995, 2005), when excessively large resources are needed for the search of the target the distractors are inhibited during the search process. This inhibition might have modulated the search process and the occurrence of the attentional bias, a bias that will not take part until the target is detected. The paradigm and the technique that we adopted do not permit to exclude such alternative explanation.

Third, as previously found by Öhman et al. (2001), we observed shorter RTs for the detection of the feared animal target compared to the nonfeared animal within the fearful groups. Critically, these RTs had a reversed relation with the LPP amplitude (i.e. larger amplitudes-shorter RTs/smaller amplitudes-longer RTs). Another interesting aspect of our results is reflected in the absence of a differentiation in LPP amplitude between spider and snake targets in the nonfearful group despite the difference in RTs. However, there was generally a shorter LPP latency for spider targets than fear-irrelevant targets, while this difference was not present between snake targets and fear-irrelevant targets. Thus, this difference in latency might have favoured shorter RTs for spider targets and offer a possible interpretation of the shorter RTs shown for spider targets among the nonfearful participants in the first experiment.

In conclusion, to our knowledge this is the first study that has shown a differentiation between a feared and a nonfeared (but fear-relevant) animal for the LPP component. This difference was reinforced by RT data, which showed a comparable pattern of results for fearful participants. No significant effects were found for the HR or PI/NI attentional complex. The present findings suggest that the different processing occurs when the target stimulus had been attended, but no indicators for that such a differentiation would occur before the stimulus is attended were shown. The inconsistency with previous results suggesting an early differentiation (e.g., Schupp et al., 2004) might be due to the more complex stimuli used in the present study. The emerging question is the functionality of the late differential responding of the LPP component.

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