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## Research Article

## Beyond Fear

## Rapid Spatial Orienting Toward Positive Emotional Stimuli

Tobias Brosch,<sup>1,2</sup> David Sander,<sup>1,2</sup> Gilles Pourtois,<sup>1,3</sup> and Klaus R. Scherer<sup>1,2</sup><sup>1</sup>Swiss Centre for Affective Sciences, <sup>2</sup>Department of Psychology, and <sup>3</sup>Neurology and Imaging of Cognition Laboratory, University of Geneva

**ABSTRACT**—*There is much empirical evidence for modulation of attention by negative—particularly fear-relevant—emotional stimuli. This modulation is often explained in terms of a fear module. Appraisal theories of emotion posit a more general mechanism, predicting attention capture by stimuli that are relevant for the needs and goals of the organism, regardless of valence. To examine the brain-activation patterns underlying attentional modulation, we recorded event-related potentials from 20 subjects performing a dot-probe task in which the cues were fear-inducing and nurturance-inducing stimuli (i.e., anger faces and baby faces). Highly similar validity modulation was found for the P1 time-locked to target onset, indicating early attentional capture by both positive and negative emotional stimuli. Topographic segmentation analysis and source localization indicate that the same amplification process is involved whether attention orienting is triggered by negative, fear-relevant stimuli or positive, nurturance-relevant stimuli. These results confirm that biological relevance, and not exclusively fear, produces an automatic spatial orienting toward the location of a stimulus.*

The human organism is constantly bombarded by environmental stimulation. Because of capacity limits, the brain needs to select stimuli that require in-depth processing (Desimone & Duncan, 1995). In addition to physical features such as color or size (Wolfe & Horowitz, 2004), emotional relevance seems to be a central selection criterion (Vuilleumier, 2005).

Capture of selective attention by emotional stimuli<sup>1</sup> has been thoroughly documented in studies using experimental paradigms such as visual search (Brosch & Sharma, 2005; Öhman, Flykt, & Esteves, 2001) and dot-probe tasks (MacLeod, Ma-

thews, & Tata, 1986; Mogg & Bradley, 1999). In the latter (see Fig. 1), participants indicate the location or identity of a target that replaces one of two simultaneously presented pictorial cues. One cue is emotionally significant (e.g., an emotional face or word), and the other is neutral. Participants show facilitated processing if the target replaces the emotional cue, rather than the neutral cue, as reflected by improved perceptual processing (Phelps, Ling, & Carrasco, 2006) or faster response times (Lipp & Derakshan, 2005; Mogg & Bradley, 1999) at the target's location. Mogg and Bradley compared the differential impact of angry and happy faces on subsequent target processing. They found faster response times when targets replaced angry faces rather than neutral faces, but no such facilitation for happy faces compared with neutral faces. Lipp and Derakshan used fear-relevant animals (snakes, spiders) and non-fear-relevant stimuli (flowers, mushrooms) as cues and found response facilitation by fear-relevant cues similar to that observed for angry faces, results consistent with the assumed attentional priority given to threat-related stimuli (see Öhman & Mineka, 2001).

These behavioral results were confirmed in studies using the scalp event-related potential (ERP), a well-established neurophysiological measure for tracking the timing of attentional modulation in paradigms like the dot-probe task (Mangun, 1995). Converging ERP results have indicated that selective attention reliably enhances the amplitude of the early P1 exogenous visual response (e.g., Luck, Woodman, & Vogel, 2000). Amplitude modulation of the P1 as a function of deployment of visuospatial attention is thought to reflect a sensory gain-control mechanism by means of which attended locations or stimuli receive increased perceptual processing in the visual cortex (Hillyard, Vogel, & Luck, 1998). Pourtois, Grandjean, Sander, and Vuilleumier (2004) recorded ERPs during a dot-probe task and observed a selective increase in P1 amplitude for targets replacing a fearful face compared with those replacing a neutral or happy face.

These and other results (for reviews, see Compton, 2003; Vuilleumier, 2005) imply that early modulation of attention is restricted to fear-relevant stimuli. It is thus not surprising that Öhman and Mineka's (2001) suggestion that the human brain is

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<sup>1</sup>We use "emotional stimuli" as a shorthand for "stimuli with a high potential for inducing emotion."

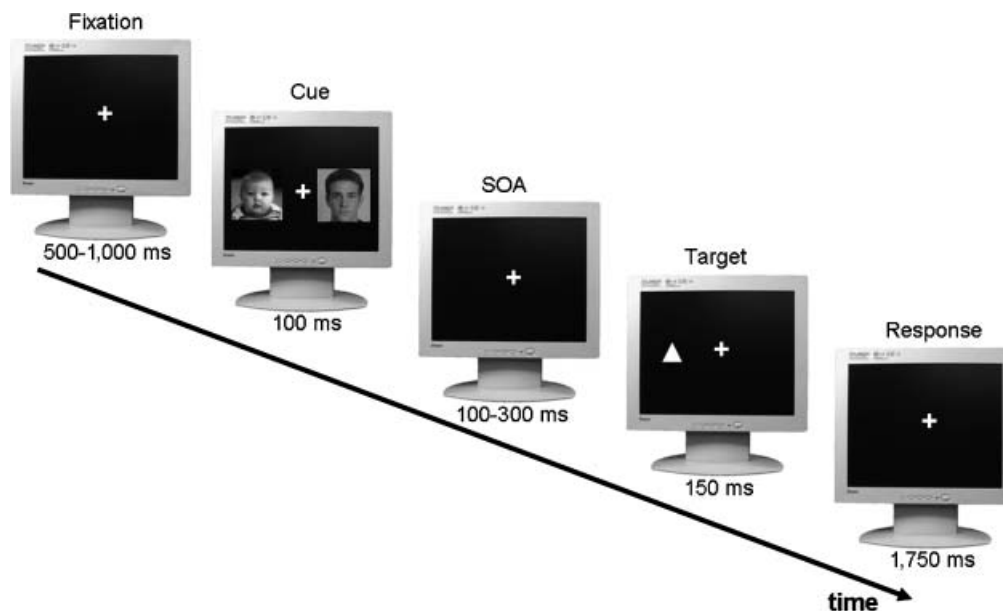
equipped with a *fear module* subserving modulation of selective attention to evolutionarily prepared threat stimuli is widely accepted. However, like other modular accounts, this explanation proposes no general mechanism; further modules need to be introduced to explain specific effects for other emotions or types of stimuli (Panksepp & Panksepp, 2000).

In contrast, appraisal theories suggest a general mechanism in which the rapid, multilevel assessment of stimulus relevance for the goals, needs, and well-being of the individual, irrespective of stimulus valence, is the central determinant of emotion (Ellsworth & Scherer, 2003). These theories predict that highly relevant stimuli requiring potential response mobilization are rapidly allocated increased amounts of attention and processing resources (Scherer, 2001). This allocation facilitates enhanced perceptual analysis of such stimuli and triggers synchronized changes in the autonomic, motor, and motivational systems to prepare the organism for adaptive behavioral responses (Sander, Grandjean, & Scherer, 2005). This general mechanism is expected to operate on different classes of stimuli, producing widely varying emotions, both negative and positive.

At first sight, the results reported earlier appear to contradict the predictions of appraisal theories, as only negative, threat-related stimuli produced attentional capture. However, most studies have compared either only fear-relevant and neutral stimuli (e.g., Brosch & Sharma, 2005; Flykt, 2005; Lipp & Derakshan, 2005; Öhman et al., 2001) or facial expressions of fear or anger and happy expressions (e.g., Fox et al., 2000; Mogg

& Bradley, 1999; Pourtois et al., 2004). Studies in the first group do not critically test the two theoretical accounts. The evidence from the second group is inconclusive because positive emotion-relevant stimuli have been represented exclusively by facial expressions of happiness. We suggest that these stimuli have a much lower level of relevance to the observer than do threat-related expressions, particularly regarding the need for rapid in-depth processing for response preparation. In real life, if someone stares at you with an angry face, you need to worry about impending aggression. If someone looks at you with a fearful face, you need to determine its cause to evaluate possible consequences for your well-being. In both cases, you need to rapidly allocate attention to the person in order to prepare an appropriate response. However, when someone smiles at you, whether from friendliness or personal happiness, no urgent response is required; the smile may be a safety signal, suggesting that you can relax.

Thus, the response-demand characteristics of angry or fearful expressions are a priori different from those of expressions of happiness. Consequently, the need for attentional capture differs in the two cases, and the experimental comparison that has been the focus of previous studies is unsuitable for testing the hypothesis that positive emotion-relevant stimuli are as likely to produce rapid attentional capture as negative stimuli are. To test this hypothesis, the experimental stimuli must be of comparable relevance, particularly as regards the mobilization of response preparation and the need for rapid in-depth analysis



**Fig. 1.** Illustration of the experimental sequence. Each trial started with a fixation cross. Then the cue, consisting of two images presented on the left and right sides of the screen, was presented briefly. One of the two pictures was an emotional face, and the other was a neutral face. Following offset of the face pair, the fixation cross was presented randomly for 100, 150, 200, 250, or 300 ms. Afterward, the target, a triangle pointing upward or downward, appeared for 150 ms in the location of one of the previously presented faces. In a valid trial, the triangle was in the location of the emotional image; in an invalid trial, the triangle was in the location of the neutral image. Some participants were required to respond if the triangle pointed upward, and the others were required to respond if the stimulus pointed downward. SOA = stimulus onset asynchrony.

(presumably the driving force behind attentional capture). Öhman and his collaborators have suggested that threat-related stimuli are treated rapidly and at a very low level of processing because of their evolutionary significance (Öhman & Mineka, 2001); such stimuli should be compared with positive emotion-relevant stimuli that are most likely to have a similar phylogenetic basis.

We suggest using photos of newborn infants for this purpose. Newborns are a prototypical example of a class of stimuli that are positive and highly biologically relevant. They can be expected to elicit a phylogenetically based readiness for response preparation (as threat does) because appropriate behavior toward newborns, such as providing warmth and nurturance, is relevant for survival of the species. The central eliciting feature could be the *Kindchenschema* (baby schema; Lorenz, 1943), a configuration of perceptual features found in newborns of various species, including a high, slightly bulging forehead; large eyes; and rounded cheeks. Lorenz observed that many animals, including humans, respond to these key stimuli with positive emotions and behavior patterns of parental care, such as approach tendencies, protective behavior, and increased attention toward the infant. The degree of *Kindchenschema* in adult faces correlates with positive attributes such as cuteness, warmth, fondness, and honesty (Berry & McArthur, 1985). Recently, we presented preliminary behavioral evidence for attentional capture by *Kindchenschema* stimuli (Brosch, Sander, & Scherer, 2007). However, behavioral data alone do not reveal whether the effect reflects modulation of early sensory perceptual processing of the target or modulation of later, postperceptual stages, such as response selection.

In the study reported here, we wanted to directly compare the attentional modulation elicited by biologically relevant stimuli with positive valence and by fear-relevant stimuli and to test the hypothesis that the underlying patterns of brain activation are highly similar in the two cases, as one would expect if a general mechanism, such as relevance appraisal, was involved in processing the stimuli. We recorded electroencephalographic (EEG) data as participants performed a standard dot-probe task (MacLeod et al., 1986) in which the emotional stimuli were fear-relevant angry faces and positive-emotion-relevant baby faces. We predicted modulation of the P1 in the form of larger amplitudes toward validly cued targets compared with invalidly cued targets. The hypothesis that attentional modulation for positive and negative stimuli is driven by the same appraisal process predicted that this P1 modulation would be similar for the angry faces and baby faces.

To formally test the hypothesis that there is one common underlying process, we complemented the conventional ERP analysis with topographic segmentation analysis (Michel, Seeck, & Landis, 1999). The latter is a data-driven analysis that considers the entire electric field without any a priori choice of channels or time frames, as typically required by conventional ERP analysis (Picton et al., 2000). Stable topographic maps of scalp electrical activity are identified using a standard clustering method (Pascual-Marqui, Michel, & Lehmann, 1994). Different scalp maps necessarily denote activation of distinct configura-

tions of intracranial generators (Lehmann & Skrandies, 1980). This method has been applied in various domains of psychology and neuroscience to gain insight into the spatiotemporal dynamics of sensory or cognitive processes (see Michel et al., 1999). In this experiment, it was important to establish whether the scalp topography that emerged (and not only the measured amplitude or latency of predefined ERP components) would differ substantially between the angry and the baby conditions. We predicted that the configuration of the electric field corresponding to the P1 ERP component (and the estimated generating source) would be identical for the two types of faces, and that only the cuing manipulation would produce a change in the strength of electrical activity (greater activation in the valid condition than in the invalid condition).

## METHOD

### Participants

Twenty University of Geneva students (15 females, 5 males; mean age = 24.0 years) participated in the EEG experiment. Thirteen others (all females; mean age = 23.4 years) participated in a behavioral control experiment. All participants were right-handed, had normal or corrected-to-normal vision, and had no history of psychiatric or neurological diseases.

### Stimuli

The stimuli for the *anger trials* consisted of eight gray-scale images showing adult faces with angry expressions and eight gray-scale images showing adult faces with neutral expressions (taken from Ekman & Friesen, 1976). The stimuli for the *baby trials* consisted of gray-scale images taken from the Internet; eight showed infant faces with neutral expressions, and eight showed adult faces with neutral expressions. Quantitative analyses confirmed that the anger and baby stimulus sets did not differ statistically in luminance, contrast, or mean energy in spatial-frequency bands.

### Procedure

The experiment consisted of one practice block of 12 trials, followed by four experimental blocks of 160 trials each. In the two blocks of baby trials, neutral baby and neutral adult faces were presented, and in the two blocks of anger trials, angry adult and neutral adult faces were shown. Block order was counter-balanced across participants.

In the EEG experiment, we included only a small number (10%) of trials that required a motor response (i.e., go trials). In the vast majority of trials (no-go trials, 90%), no overt motor response was required. This design allowed us to study covert spatial orienting toward emotional stimuli without contamination of EEG signal quality by motor preparation or execution. The behavioral control experiment used the same stimuli and task as the EEG experiment. The only difference was that we increased the number of go trials from 10% to 50% in order to collect enough behavioral responses for statistical analyses.

On each trial (see Fig. 1), a fixation cross (presented for a randomly selected duration between 500 and 1,000 ms) was followed by a cue consisting of two images, one on either side of the screen. The cue was presented briefly (100 ms) to avoid any systematic saccadic eye movement. One of the two pictures always showed an emotional face, and the other showed a neutral one. The pictures were randomly selected from within each emotion category. The images measured  $7 \times 10$  cm, and the distance between the fixation cross and the center of each image was 15 cm. Participants were seated in front of the screen at a viewing distance of 100 cm, resulting in a visual angle of  $8.5^\circ$  between the fixation cross and the center of each image. Following offset of the face pair, the fixation cross was presented for a randomly selected interval of 100, 150, 200, 250, or 300 ms. Afterward, the target, a triangle pointing upward or downward, appeared for 150 ms, in the location of one of the prior images. On valid trials, the triangle appeared at the location previously occupied by the emotional image (anger or baby); on invalid trials, the triangle appeared at the location previously occupied by the neutral image. Valid and invalid trials were presented in randomized order in equal proportions (.50).

Participants were instructed to use their right index finger to press the “B” key of the response keyboard when the triangle was in a particular orientation (pointing upward or downward, counterbalanced across participants). They had a maximum of 1,750 ms to respond, after which the next trial started.

### EEG Recording

EEG was recorded with a sampling rate of 512 Hz using the ActiveTwo system (BioSemi, Amsterdam, The Netherlands). Electro-oculogram was recorded using four facial electrodes placed on the outer canthi of the eyes and in the inferior and superior areas of the left orbit. Scalp EEG was recorded from 64 Ag/AgCl electrodes attached to an electrode cap and positioned according to the extended 10–20 system. The EEG electrodes were referenced off-line to average reference. Data were filtered using a high pass of 0.53 Hz and a low pass of 30 Hz, down-sampled to 256 Hz, and segmented around target onsets in epochs of 600 ms (from  $-200$  ms to  $+400$  ms). The algorithm developed by Gratton, Coles, and Donchin (1983) was used to reduce artifacts from eye movements. Baseline correction was performed using the 200-ms prestimulus interval. EEG epochs in which the signal exceeded  $70 \mu\text{V}$  were excluded. Artifact-free epochs were averaged separately for each electrode, condition, and individual. Bad channels were interpolated using spherical splines. Grand-average ERPs were generated by computing mean ERPs across subjects in each condition.

### Data Analysis

#### *Behavioral Control Experiment*

To assess modulation of perceptual sensitivity by cue validity, we calculated the discrimination measure  $d'$ , which is based on

signal detection theory (Green & Swets, 1966). In the present experiment, higher  $d'$  values indicate that the signal (compared with noise) at a given location is more salient and more easily recognized. The  $d'$  values were analyzed using a repeated measures analysis of variance (ANOVA) with the factors of emotion type (baby, anger) and cue validity (invalid, valid).

#### *EEG Experiment*

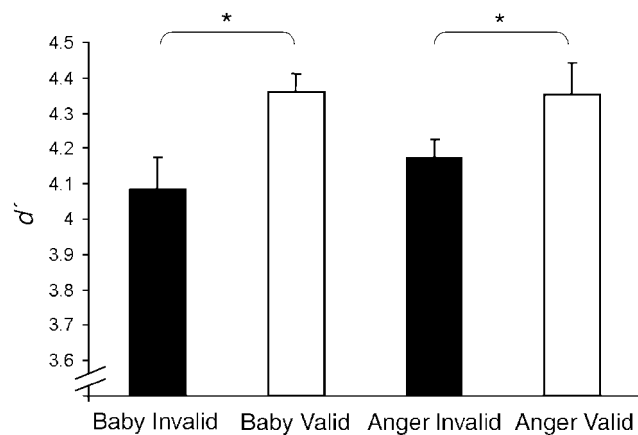
First, we performed classical ERP analyses (Picton et al., 2000). To test our a priori hypotheses, we analyzed the P1 component (120–170 ms) time-locked to target onset in valid and invalid trials. P1 amplitudes and latencies were measured at lateral occipital sites, where amplitudes for this component were maximal (PO3/PO7 and PO4/PO8). These sites had shown related effects in previous studies (Di Russo, Martinez, & Hillyard, 2003; Pourtois et al., 2004). Amplitudes and latencies of P1 were analyzed using a  $2 \times 2 \times 2 \times 2 \times 2$  ANOVA with the repeated factors of emotion type (baby, anger), cue validity (invalid, valid), target side (left, right), hemisphere (left, right), and electrode position (inner: PO3, PO4; outer: PO7, PO8).

Next, we analyzed topographic changes in the ERP data using a conventional clustering method (Pascual-Marqui et al., 1994). We identified the dominant scalp topographic maps of global explained variance in the grand-average ERP data by performing a K-means clustering on all four conditions (2 emotion types  $\times$  2 cue validities) concurrently from target onset until 400 ms after target onset. Dominant scalp maps were identified using an objective cross-validation criterion. We statistically verified the reliability of the dominant maps by fitting them to individual subjects' ERP data. The rationale of this temporal segmentation method has been extensively described elsewhere (Michel et al., 1999), and the clustering method has already been applied to analyze ERP data collected during attentional and emotional paradigms (Pourtois, Thut, Grave de Peralta, Michel, & Vuilleumier, 2005). To estimate the likely configuration of intracranial neural sources underlying the observed scalp topographic maps of interest, we used a distributed inverse solution method derived from biophysical laws describing electrical fields in the brain (local auto-regressive average, or LAURA; see Grave de Peralta Menendez, Gonzalez Andino, Lantz, Michel, & Landis, 2001). This method computes a three-dimensional reconstruction of the generators of the brain's electromagnetic activity measured at the scalp from biophysically driven inverse solutions, without a priori assumptions about the number and position of possible generators.

## RESULTS

### **Behavioral Performance in the Control Experiment**

Statistical analyses of  $d'$  scores (see Fig. 2) showed a main effect of cue validity,  $F(1, 12) = 30.91, p < .001, \eta_p^2 = .72$ . Discrimination of the target's orientation was reliably better on valid than on invalid trials. Post hoc  $t$  tests showed significant validity effects for both the anger condition,  $t(12) = 2.26, p = .02$



**Fig. 2.** Results from the behavioral control experiment:  $d'$  values as a function of condition (2 emotion types  $\times$  2 cue validities). Asterisks indicate significant differences between conditions.

(one-tailed), and the baby condition,  $t(12) = 3.82$ ,  $p = .001$  (one-tailed). Neither the main effect of emotion type nor the interaction of emotion type and cue validity reached statistical significance, both  $F_s < 1$ ,  $p_s > .45$ .

### ERP Analysis

Data from 1 female participant were excluded because of poor quality of the electrophysiological recordings. Figure 3a shows the potentials time-locked to target onset, averaged across all conditions. Figure 3b shows ERPs at electrode PO7 for baby trials and anger trials in the valid and invalid conditions.

The main effect of cue validity,  $F(1, 18) = 16.03$ ,  $p = .001$ ,  $\eta_p^2 = .47$ , indicated that P1 amplitude was larger on valid (2.2  $\mu\text{V}$ ) than on invalid (1.7  $\mu\text{V}$ ) trials. This effect was driven mainly by targets presented to the left visual field, as indicated by the Cue Validity  $\times$  Target Side interaction,  $F(1, 18) = 4.518$ ,  $p = .05$ ,  $\eta_p^2 = .20$ . The Emotion Type  $\times$  Cue Validity interaction was not statistically significant,  $F(1, 18) = 0.07$ ,  $p = .20$ . For latency of the P1, neither the main effect of cue validity nor the Emotion Type  $\times$  Cue Validity interaction was statistically significant,  $F_s < 1$ ,  $p_s > .60$ . The statistical power ( $1 - \beta$ ) for detecting a large effect was .90 for the main effects and .99 for the interactions (Cohen, 1988).

A separate analysis of the baby trials revealed that P1 amplitude was larger on valid (2.2  $\mu\text{V}$ ) than on invalid (1.7  $\mu\text{V}$ ) trials, as indicated by the significant main effect of cue validity,  $F(1, 18) = 9.44$ ,  $p = .007$ ,  $\eta_p^2 = .34$ . For latency of the P1, the main effect of cue validity was not statistically significant,  $F(1, 18) = 0.06$ ,  $p = .80$ . On valid trials, the P1 peaked earlier for targets presented to the right visual field (148 ms) than for targets presented to the left visual field (153 ms), as indicated by the significant Cue Validity  $\times$  Target Side interaction,  $F(1, 18) = 5.4$ ,  $p = .032$ ,  $\eta_p^2 = .23$ .

Similarly, a separate analysis of the anger trials revealed that P1 amplitude was larger on valid (2.2  $\mu\text{V}$ ) than on invalid

(1.8  $\mu\text{V}$ ) trials, as indicated by the significant main effect of cue validity,  $F(1, 18) = 9.33$ ,  $p = .007$ ,  $\eta_p^2 = .34$ . For latency of the P1, the main effect of cue validity was not statistically significant,  $F(1, 18) = 0.101$ ,  $p = .75$ .

### Temporal Segmentation and Source Localization

Temporal segmentation was performed for each of the four conditions (2 emotion types  $\times$  2 cue validities), from target onset until 400 ms poststimulus. Spatial cluster analysis revealed that grand-average ERP data were modeled reliably by a solution including a sequence of eight different maps. This solution explained 95.3% of the total variance. Given our a priori hypotheses related to the P1, we further analyzed the map that corresponded to the manifestation of the P1 (see Fig. 4a). Subsequent statistical analyses confirmed that this map was identical across the four conditions, suggesting that the neural generators at the origin of the P1 were indistinguishable across the specific conditions.

A  $2 \times 2$  ANOVA with the factors of emotion type (baby, anger) and cue validity (invalid, valid) was performed on the global explained variance of the P1 map. Most important, no differences between anger and baby trials were found; neither the main effect of emotion type,  $F < 1$ ,  $p = .93$ , nor the Emotion Type  $\times$  Cue Validity interaction,  $F(1, 18) = 2.598$ ,  $p = .12$ , was statistically significant. The only significant effect was a main effect of cue validity,  $F(1, 18) = 4.79$ ,  $p = .04$ ,  $\eta_p^2 = .21$ ; the global variance explained by the P1 map was greater for valid (mean global explained variance, GEV = 30) than for invalid (mean GEV = 23) trials, a finding consistent with the outcome of the conventional P1 ERP analysis reported earlier.

Finally, we confirmed that the intracranial generators of the P1 were located in striate and extrastriate visual cortex (see Fig. 4b), a pattern that has been found repeatedly when examining generators of this early visual response (e.g., Martinez et al., 1999).<sup>2</sup>

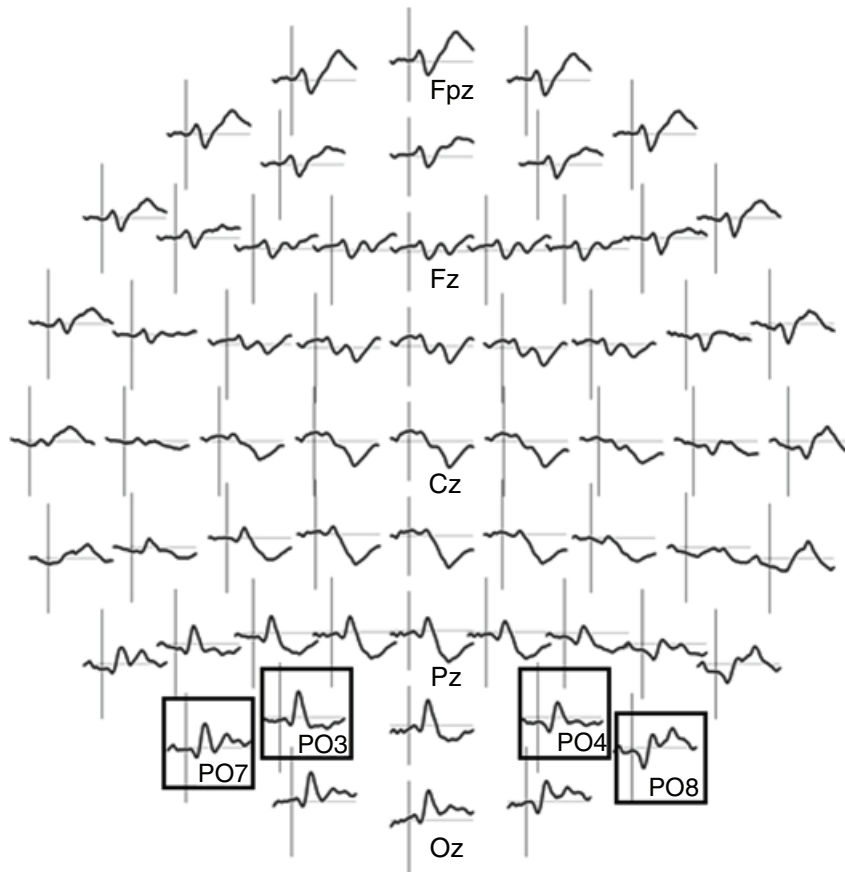
## DISCUSSION

In this study, we tested the hypothesis that biologically relevant stimuli with a positive valence and fear-relevant stimuli may elicit attentional modulation with similar time courses and underlying neural generators.

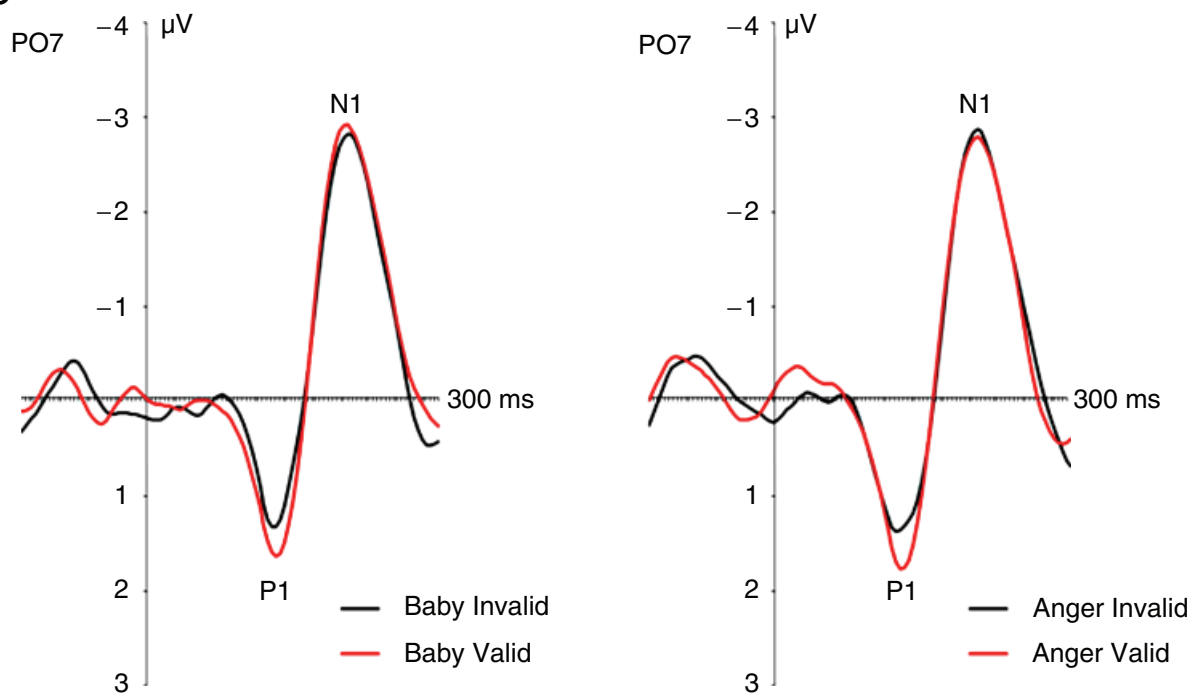
Analysis of behavioral data showed a reliable gain in orientation discrimination of the target on valid trials, relative to invalid trials, in both the positive-emotion (baby) and the negative-emotion (anger) conditions. This finding extends the preliminary results we reported previously (Brosch et al., 2007) and contrasts

<sup>2</sup>The reliability of the source localization was confirmed using brain electrical source analysis (BESA; Scherg, Vajsar, & Picton, 1989), a distinct inverse solution method. The results of that analysis are highly compatible with the LAURA solution.

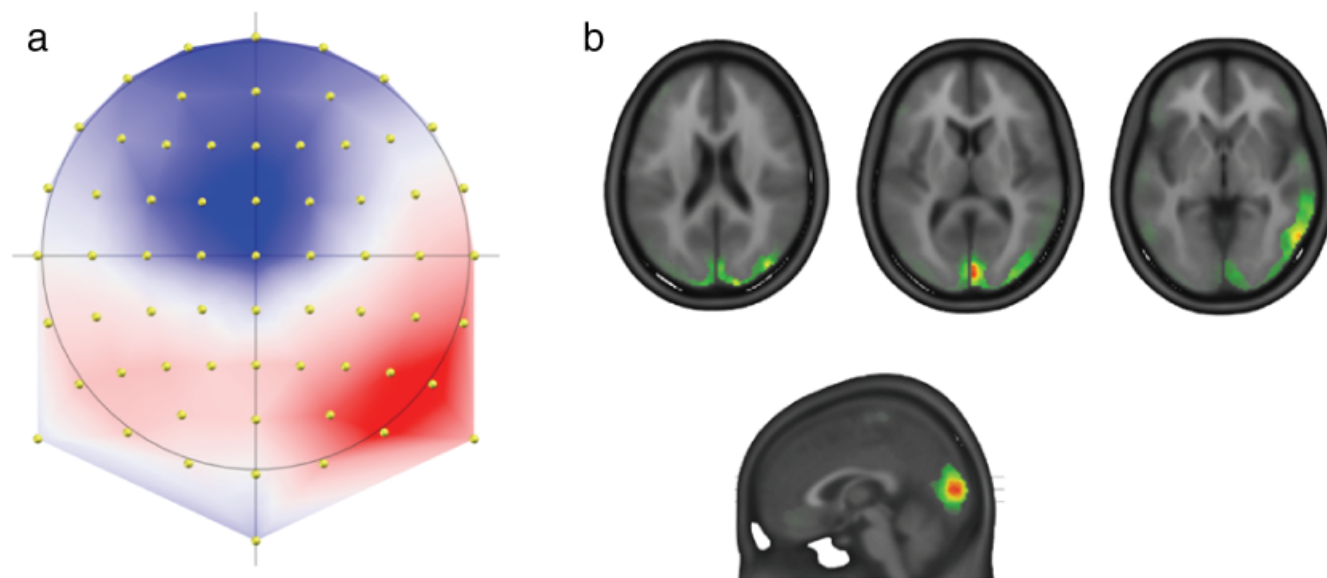
a



b



**Fig. 3.** Results from the event-related potential (ERP) analysis: (a) ERPs at each electrode, time-locked to the onset of the target and averaged across all conditions, and (b) ERPs at electrode PO7 in the valid and invalid conditions on baby trials (left panel) and anger trials (right panel). The electrodes selected for further statistical analyses are outlined by boxes in (a).



**Fig. 4.** Result of the topographic segmentation: (a) map representing the P1 potential (collapsing across the target presentation in left and right visual fields) and (b) inverse solution (based on local auto-regressive average, or LAURA) for the map representing the P1 potential in all four conditions.

with results from previous studies that found an effect when using negative cues (angry faces) but not positive cues (happy faces).

Analysis of the P1 component revealed higher amplitudes for validly than for invalidly cued targets, in both the baby and the anger conditions. This effect reflects early orientation of spatial attention toward the location of emotional cues. It is plausible to assume that our results were due to the emotional cues' high biological relevance, and the resulting need for in-depth stimulus processing in the service of response or action preparation. However, despite our efforts at experimental control, we cannot exclude the possibility that other stimulus characteristics were responsible for the effects or contributed to them. Further work needs to establish the robustness of the hypothesized effect.<sup>3</sup>

The topographic brain activity during the time course of the P1 is best explained by a dominant map that is indistinguishable across the four conditions. This topographic map explains more global variance for valid than for invalid trials, an observation that corroborates the ERP findings of increased P1 amplitude on valid trials. Source localization for this map suggests generators of the P1 component in striate and occipito-temporal extrastriate areas. It is noteworthy that conventional ERP analyses and topographic segmentation analysis converged on two central findings: (a) Both the fear-relevant and the positive stimuli modulated attention relatively early during stimulus processing, and (b) the same (or highly similar) amplification processes and neural struc-

tures seemed to be involved in attention orienting triggered by fear-relevant and positive-emotion-relevant stimuli.

This evidence strongly supports the idea that a common appraisal process underlies attentional modulation toward various kinds of relevant stimuli. The classical ERP analyses were based on previous work on attentional modulation and a priori hypotheses about electrode position and the time course of modulation (Luck et al., 2000; Pourtois et al., 2004), whereas the data-driven topographic analysis did not make any a priori assumptions about the spatial orienting effect in the ERP data. The similarity between the results obtained using these two complementary methods is remarkable and confirms the robustness of the attentional-modulation effect.

In conclusion, by choosing a stimulus type that was expected to have biological relevance comparable to that of threat stimuli, we obtained highly similar attentional-modulation effects for positive and negative emotional stimuli. Such effects have not been demonstrated in previous studies that used happy faces as positive stimuli.

Most important, this study provides the first evidence that brain-activation patterns underlying attentional capture are similar for negative and positive stimuli and seem to be generated by the same brain structures. This evidence suggests that a fear module dedicated to processing fear-relevant stimuli is not needed to account for attentional orienting. Rather, our results suggest that a common early and probably automatic appraisal of relevance modulates attentional resources allocated to negative (including fear-related) and positive stimuli that are highly relevant for the organism and involve response preparation. It could be argued that our results provide evidence only for the similarity of the final efferent outcome of attention recruitment,

<sup>3</sup>One might hypothesize that seeing more adult faces than baby faces during the experiment drove the attentional-capture effect. However, when we analyzed only data from the first experimental block for participants who started with a block of baby trials, we obtained a highly similar pattern of results. This suggests that it was not the relative frequency of baby stimuli, but rather their emotional relevance, that captured attention.



which could be triggered by two different detection modules. However, there is little evidence for the existence of such modules (and no coherent account of the structures and mechanisms involved), and an increasing number of studies show that the amygdala (often suggested as the location of a fear module; Calder, Lawrence, & Young, 2001; Öhman & Mineka, 2001) is strongly involved in the general processing of relevance, including relevance of positive stimulation (Fitzgerald, Angstadt, Jelsone, Nathan, & Phan, 2006; Sander, Grafman, & Zalla, 2003). Therefore, it is more parsimonious and more plausible to assume a general appraisal mechanism based on relevance detection in the service of response preparation. We suggest that this theoretical framework should be accorded a privileged position in further research and that future studies should explore the precise nature of the relevance appraisal required for a stimulus to capture attention.

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