Erschienen in: Social Cognitive and Affective Neuroscience ; 9 (2014), 11. - S. 1738-1745

Explicit semantic stimulus categorization interferes with implicit emotion processing

Harald T. Schupp, Ralf Schmälzle, and Tobias Flaisch
Department of Psychology, University of Konstanz, 78457 Konstanz, Germany

Previous functional magnetic resonance imaging and event related brain potential studies revealed that performing a cognitive task may suppress the preferential processing of emotional stimuli. However, these studies utilized simple and artificial tasks (i.e. letter, shape or orientation discrimination tasks), unfamiliar to the participants. The present event related potential study examined the emotion attention interaction in the context of a comparably more natural scene categorization task. Deciding whether a natural scene contains an animal or not is a familiar and meaningful task to the participants and presumed to require little attentional resources. The task images were presented centrally and were overlaid upon emotional or neutral background pictures. Thus, implicit emotion and explicit semantic categorization may compete for processing resources in neural regions implicated in object recognition. Additionally, participants passively viewed the same stimulus materials without the demand to categorize task images. Significant interactions between task condition and emotional picture valence were observed for the occipital negativity and late positive potential. In the passive viewing condition, emotional background images elicited an increased occipital negativity followed by an increased late positive potential. In contrast, during the animal / non animal categorization task, emotional modulation effects were replaced by strong target categorization effects. These results suggest that explicit semantic categorization interferes with implicit emotion processing when both processes compete for shared resources.

Keywords: emotion; attention; ERP; EPN; LPP; competition

INTRODUCTION

The preferential processing of high priority stimuli in the environment is an essential function of selective attention. Emotional stimuli may command attentional resources and priority processing due to their intrinsic stimulus significance (Lang *et al.*, 1997; Schupp *et al.*, 2006). Research utilizing event related brain potentials (ERPs) determined that the processing of high arousing pleasant and unpleasant compared with low arousing control images is associated with a negative going potential over temporo occipital sensor regions around 150 300 ms poststimulus. This occipital negativity effect may reflect a transitory processing period within which emotional stimuli are selected for elaborate processing (Junghofer *et al.*, 2001; Schupp *et al.*, 2003, 2007b). Subsequently, emotionally arousing as compared with neutral and non arousing stimulus processing is associated with an enlarged late positive potential between 300 and 700 ms poststimulus. The enlarged late positive potential (LPP) is considered as a measure of the allocation of processing resources in a capacity limited processing stage associated with stimulus representation in working memory (Schupp *et al.*, 2006, 2007b; Herrmann *et al.*, 2007; Sabatinelli *et al.*, 2013). Thus, ERP components with distinct polarity, topography and timing reveal various effects of selective attention brought out by emotionally salient stimuli.

A number of studies have explored emotional stimulus processing while participants concurrently performed a primary cognitive task. Functional MRI (fMRI) and ERP studies demonstrated that focusing visual attention on stimuli relevant to the current task goals interfered with the preferential processing of emotionally relevant stimuli, which were unrelated to the primary task at hand. For instance, participants in an fMRI study had to discriminate the orientation of eccentrically presented bars while maintaining fixation on centrally presented emotional or neutral faces (Pessoa *et al.*, 2002a). Under task load, as compared with control conditions, processing of emotional compared with neutral faces was not associated with increased activation in associative visual processing areas or the amygdala (Pessoa *et al.*, 2002a; see also Erthal *et al.*, 2005; Mitchell *et al.*, 2007). Similar findings were seen in ERP research investigating spatial and object based attention tasks (e.g. Holmes *et al.*, 2003; Schupp *et al.*, 2008; De Cesarei *et al.*, 2009; Wiens *et al.*, 2011, 2012): Directing attention away from emotional and neutral pictures by a concurrent task resulted in reduced emotional modulation of distinct ERP components. Theoretically, these findings are often considered from the 'competition for processing' perspective, according to which the processing advantage of emotional cues depends on the availability of processing resources shared with the explicit task (Pessoa *et al.*, 2002b).

Previous research examining the emotion attention relationship commonly used discrimination tasks based on 'synthetic' stimuli, i.e. letter, object and shape discrimination, which were unfamiliar and meaningless to the participants (e.g. Schupp *et al.*, 2008; De Cesarei *et al.*, 2009; Wiens *et al.*, 2011). However, the emotion attention relationship in 'competition for processing' conditions may vary depending on the nature of the primary attention task. This issue has been explored in a series of studies (Fei Fei *et al.*, 2005; see also Li *et al.*, 2002), which systematically examined the attentional requirements for a natural stimulus categorization task (i.e. detecting the presence of an animal) and discrimination tasks based on 'synthetic' stimuli (i.e. stimulus orientation of letters). The crucial finding of these studies was that under taxing dual task conditions, the higher order natural scene categorization was achieved in the near absence of attention. In contrast, presumably much 'simpler' tasks requiring color or stimulus orientation processing consumed attentional resources. These findings raise the issue of whether previous findings of interference with emotion processing are specific to the particular class of 'simple', unfamiliar and meaningless tasks used in these studies. Probing the processing advantage of emotional stimuli in the context of a natural scene categorization task extends previous research regarding the 'competition for processing' perspective to a novel task, which is familiar and meaningful to the participants, requires little attentional resources and may consequently show little interference with obligatory emotion

---

We thank Dr. Jessica Stockburger and Ines Krug for their assistance in data collection and analysis. This work was supported by the German Research Foundation (Deutsche Forschungsgemeinschaft Schu 1074/10 3).

Correspondence should be addressed to Harald Schupp, Department of Psychology, University of Konstanz, PO Box 36, 78457 Konstanz, Germany. E mail: harald.schupp@uni konstanz.de

processing. Furthermore, implicit emotion and explicit task demands appear similar with respect to the processing demands in the ventral stream implicated in object recognition, in that both conditions consist of natural scenes. As a result, the issue of parallel processing in the visual stream and the obligatory detection of emotional significance can be specifically addressed as a function of high level constraints imposed by an explicit task goal (Rousselet *et al.*, 2004).

This study examined the processing of emotional and neutral stimuli in the context of a primary natural scene categorization task. To achieve this, task relevant natural scenes depicting centered animal and non animal pictures were overlaid upon emotional scenes unrelated to the task images. Participants were instructed to indicate whether the natural scene contained an animal (active categorization task). To determine whether natural scene processing interferes with the preferential processing of emotional stimuli, we examined the occipital negativity and LPP component, which are the two main ERP markers of emotional attention (Schupp *et al.*, 2006). The hypothesis that natural scene processing demands minimal processing resources predicts that emotional stimuli are preferentially processed even when participants perform a distracting natural scene categorization task (Li *et al.*, 2002; Fei Fei *et al.*, 2005). Alternatively, an interference effect may be observed from the perspective that emotional background and natural scene foreground processing compete for shared processing resources. Previous research on either explicit categorization or implicit emotion processing observed very similar ERP modulations, i.e. an increased occipital negativity between 150 and 300 ms after stimulus onset followed by an increased late positive potential around 300 700 ms (Schupp *et al.*, 2007a; Ferrari *et al.*, 2008). Thus, interference effects may reveal competition for processing resources in higher order visual regions implicated in object recognition, which are shared by primary task and secondary emotion processing (cf. Lavie, 2005). A passive viewing condition (counterbalanced across participants) served as a control task to assure that the identical stimuli elicit preferential emotion processing, i.e. an increased occipital negativity and late positive potential to emotional *vs* neutral background stimuli.

METHODS

Participants

A total of 24 (12 females) right handed students from the University of Konstanz without reported neurological or psychiatric problems participated in the study. They received either course credits toward their research requirements or 10 €. Participants were between the ages of 18 and 24 years (*M* 21). All participants provided written informed consent to the protocol approved by the Review Board of the University of Konstanz.

Stimulus materials

Each stimulus consisted of a task relevant target picture in the center (280 × 220 pixels) overlaid on a task irrelevant background picture (720 × 540 pixels; see Figure 1). Task and background pictures were separated by a small white frame. The target stimuli were drawn from widely available commercial databases and comprised 150 animal images (mammals, birds, fish, arthropods and reptiles) and 150 images depicting non animal content (outdoor and indoor scenes, tools and kitchen utensils). Emotional and neutral background pictures were drawn from the International Affective Picture System (IAPS, Lang *et al.*, 2008) and comprised 3 × 100 pictures with pleasant (erotica, sports, babies and food), unpleasant (mutilation, injury, grief and pollution) and neutral contents (people in everyday life situations, objects and landscapes). Normative valence ratings differed for pleasant (*M* 6.7, s.d. 0.76), unpleasant (*M* 2.5, s.d. 0.73) and neutral (*M* 5.4, s.d. 0.73) pictures [*F*(2,296) 855.2, $P < 0.0001$; *t*s > 12, *P*s < 0.001]. Similarly, categories differed regarding normative ratings of arousal [pleasant *M* 5.5, s.d. 0.93; neutral *M* 3.2, s.d. 0.67; unpleasant *M* 5.9, s.d. 0.85; *F*(2,296) 303.5, $P < 0.0001$; *t*s > 3.4, *P*s < 0.001].

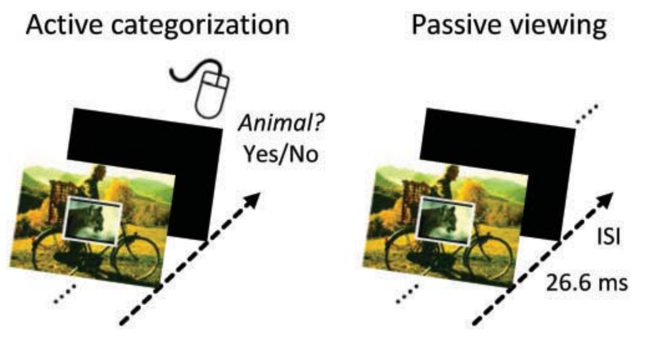

Fig. 1 Illustration of the stimuli and paradigm for the active categorization and passive viewing conditions.

To address the concern that overlaying a central picture may compromise the emotional quality of the background IAPS materials, 15 representative pictures from each category were rated at the end of the experiment on emotional dimensions of valence and arousal using the Self Assessment Manikin (Bradley and Lang, 1994). Using the same presentation parameters as in the main experiment, pictures were presented briefly (26.6 ms), and participants were asked to evaluate the background IAPS picture. Confirming the a priori categories of pleasant, neutral and negative images, highly significant main effects were observed for valence and arousal ratings, *F*s(2,28) 26.2 and 22.2, *P*s < 0.0001, respectively. Pleasant pictures were evaluated more positively (*M* 6.5, s.d. 0.84) compared with neutral images (*M* 5.5, s.d. 0.67), $P < 0.001$, and aversive pictures (*M* 3.8, s.d. 1.4) were judged as more unpleasant than neutral contents, $P < 0.01$. Regarding arousal reports, pleasant and unpleasant picture categories (*M* 4.5 and 4.4, s.d. 0.99 and 0.95) were rated as more arousing as compared with neutral cues (*M* 2.6, s.d. 0.5), *P*s < 0.001. The pattern of emotional differentiation is somewhat reduced as compared with the normative ratings. However, this finding is consistent with previous research showing similar effects for speeded presentation times and reduced picture size (Codispoti and Cesarei 2007; Codispoti *et al.*, 2009).

Procedure

The experiment consisted of two separate conditions in which participants were asked to either perform an explicit categorization task or to passively view the stimuli (see Figure 1). The order of the two conditions was counterbalanced across participants.

The explicit categorization task was similar to those used in previous research (Codispoti *et al.*, 2006b; Ferrari *et al.*, 2008). Specifically, participants were asked to detect pictures displaying an animal. To minimize differences across target (animal pictures) and non target trials (non animal pictures) with regard to motor activation, participants pressed one button with the index or middle finger to indicate the presence of an animal and another button if the picture did not contain an animal (two alternative forced choice tasks; response assignment counterbalanced across participants). Animal and non animal items were presented with equal probabilities of 50% in a pseudo randomized fashion allowing for sequences of at most three pictures of each category (animal and non animal). Order of presentation was balanced with respect to valence of the background picture so that no more than two repetitions of the same valence occurred. The assignment of central and background pictures was randomized, separately for each participant and task condition.

The second condition was a passive viewing condition. This condition used the same stimulus materials and parameters of stimulus presentation as used in the active task condition with the critical difference that participants had no explicit task instruction. They were told to keep their eyes comfortably focused on the fixation cross in the center of the screen and to simply view the pictures.

To ensure a good signal to noise ratio, active and passive conditions included 1200 trials each (i.e. four repetitions of the entire stimulus set). Each trial consisted of the presentation of a picture for 26.6 ms, followed by an inter stimulus interval varying between 750 and 1250 ms during which participants had to respond in the active task condition. Brief exposure times (~25 ms) are sufficient to elicit neural indices of explicit and implicit stimulus categorization (Thorpe *et al.*, 1996; Ferrari *et al.*, 2008; Peyk *et al.*, 2009) and prevent scanning eye movements, effectively abolishing serial processing of central and peripheral visual information (Christianson *et al.* 1991). Using Presentation software (Neurobehavioral Systems, Inc., Albany, CA), the pictures were shown on a 22 inch CRT monitor (75 Hz refresh rate) located approximately 75 cm in front of the participant. Picture presentation lasted for 40 min, interrupted by short breaks to allow for posture adjustments.

Analysis of behavioral responses

For animal and non animal items, the proportion of correct responses, as well as response times, was calculated and submitted to a repeated measure ANOVA including the factors Target Category (animal *vs* non animal) and Valence Category (pleasant *vs* neutral *vs* unpleasant).

ERP recordings and analysis

ERP recording

Brain and ocular scalp potential fields were measured with a 256 lead geodesic sensor net (HCGSN), on line bandpass filtered from 0.1 to 100 Hz, and sampled at 250 Hz using Netstation acquisition software and EGI amplifiers (Electrical Geodesics, Inc., Eugene, OR). Electrode impedance was kept below 70 kΩ, as recommended for this type of electroencephalogram (EEG) amplifier by EGI guidelines. Data were recorded continuously with the vertex sensor as reference electrode. A 40 Hz digital low pass filter was applied off line to the continuous EEG data. Data editing and artifact rejection were based on an elaborate method for statistical control of artifacts, specifically tailored for the analyses of dense sensor ERP recordings (Junghofer *et al.*, 2000). The reported data were corrected for ocular artifacts based on a multiple regression method (Miller *et al.*, 1988), baseline adjusted (100 ms prestimulus) and converted to an average reference. Finally, separate average waveforms were calculated for the 12 experimental cells [Task (2) × Target Category (2) × Valence Category (3)] for every sensor and participant. Applying strict artifact criteria, 76.7% of the trials were used on average to calculate the average waveforms, which were not different across experimental categories (s.d. 1.0).

Previous neuroimaging studies observed most pronounced blood oxygenation level dependent (BOLD) signal and ERP differences over visual associative brain regions toward high arousing pictures (Bradley *et al.*, 2001; Schupp *et al.*, 2003; Sabatinelli *et al.*, 2005). Thus, statistical analysis of emotional IAPS pictures was based on pleasant and unpleasant images high in emotional arousal. Specifically, the three valence categories entering analysis consisted of picture contents showing erotic scenes (erotica), scenes of mutilation and injury (mutilation), and people in everyday life situations (people), respectively. Control analyses including all picture materials revealed a similar pattern of results as reported. Including low arousing picture contents in the two emotional categories provides a much less conclusive test for examining the resource dependency of implicit affective categorization and is not reported for brevity.

Visual inspection and single sensor waveform analyses, calculated for each sensor and time point, served to identify effects due to emotion and target conditions during passive and active viewing, respectively, and to determine higher order interaction effects. Based on this exploratory analysis, an occipital negativity and late positive potential component were scored as mean activity in selected sensor regions and time windows.

Early ERP differences: occipital negativity

As expected, explicit and implicit categorization was associated with a relative negative potential over posterior sites. To capture early ERP effects, the mean activity over a time interval from 200 to 300 ms was calculated in left and right temporo occipital sensor clusters (EGI sensor numbers of the left cluster: 82, 83, 92, 93, 94, 95, 96, 102, 103, 104, 105, 106, 107, 108, 112, 113, 114, 115, 116, 117, 118, 121, 122, 123, 124, 125, 134, 135, 136; right cluster: 140, 150, 151, 152, 158, 159, 160, 161, 162, 167, 168, 169, 170, 171, 175, 176, 177, 178, 179, 180, 188, 189, 190, 191, 192, 200, 201, 202, 209).

Late ERP differences: late positive potential

As expected, inspection of the ERP waveform revealed increased positive potentials toward targets (*vs* non targets) in the explicit categorization condition and toward emotionally arousing (*vs* neutral) pictures in the passive viewing condition between 300 and 600 ms after stimulus onset (Codispoti *et al.*, 2006a; Schupp *et al.*, 2007b). However, the task effects were maximally pronounced between 300 and 450 ms whereas emotion effects appeared between 450 and 600 ms. Accordingly, mean amplitudes from representative centro parietal sensor clusters (EGI sensor numbers of the left cluster: 9, 43, 44, 51, 52, 59, 65, 77, 78, 79, 86, 87, 88, 98, 99; right cluster: 130, 131, 132, 133, 142, 143, 144, 145, 154, 155, 156, 165, 185, 186, 187) were averaged for each of the two time intervals, i.e. 300 450 and 450 600 ms, respectively.

Statistical analyses

Data for the occipital negativity were entered into ANOVAs that included the factors Task Condition (active categorization *vs* passive viewing), Target Category (animal *vs* non animal foreground picture) and Valence Category (pleasant *vs* neutral *vs* unpleasant background picture). Analysis of the late positive potential included the additional factor Time (300 450 *vs* 450 600 ms).

Initial analyses included the between subject factors Order (passive active *vs* active passive task) and Laterality (left and right). However, there were no meaningful effects involving these two factors. Accordingly, these factors were not further considered in the reported analyses.

In addition, although the results reported are based on all trials, similar results were observed for the occipital negativity and late positive potential when separate analyses were conducted based on trials with correct and incorrect behavioral responses.

When appropriate, the Greenhouse Geisser procedure was used to correct for violations of sphericity.

RESULTS

Categorization task

As expected, response times to target pictures (M 425.2 ms; s.d. 80.9) were faster as compared with non target items (M 443.7 ms; s.d. 70.3), Target Category $F(1,23)$ 16.5,

$P < 0.0001$. Emotional valence of the background picture did not modulate responding to the explicit categorization task, Valence Category *Fs* < 1.

Accuracy did not differ significantly for target (*M* 78.1%; s.d. 16.4) and non target items (*M* 82.0%; s.d. 9.3), *F*(1,13) 2.5, ns. Again, no significant main effect or interactions involving Valence Category were observed, *Fs* < 1.

Event-related potentials

The main findings are summarized in Figures 2 4 displaying representative ERP waveforms (Figures 2 and 3) and ERP difference maps [emotional neutral] and [target non target], respectively (Figure 4). In the passive viewing condition, emotional background images elicited an increased occipital negativity followed by an increased late positive potential. In contrast, during the animal / non animal categorization task, emotional modulation effects were replaced by strong target categorization effects.

Occipital negativity (200 300 ms)

The overall ANOVA indicated significant main effects of Valence Category, *F*(2,46) 11.1, $P < 0.001$ and Target Category, *F*(1,23) 12.1, $P < 0.01$. Of most interest, the interaction of Task Condition by Valence Category was significant, *F*(2,46) 5.5, $P < 0.05$. Accordingly, separate analyses were conducted for passive and active task conditions, respectively.

The analysis of the passive viewing condition revealed a significant main effect of Valence Category, *F*(2,46) 11.6, $P < 0.0001$. *Post hoc* tests indicated an increased relative occipital negativity for pleasant and unpleasant as compared with neutral IAPS background pictures, *ts*(23) 3.9 and 3.5, *Ps* < 0.005, respectively. In contrast, there was no effect of Valence Category in the active categorization condition, *F*(2,46) 1.0.

Results for the centrally presented natural scenes revealed an opposite pattern of effects. Although strong effects of Valence Category were observed during passive viewing, there was no difference in processing animal and non animal pictures, Target Category *F*(1,23) 1.5. In contrast, although no effects of Valence Category were observed during the active categorization condition, Target Category showed a significant main effect, indicating an increased occipital negativity toward animal as compared with non animal pictures, *F*(1,23) 12.9, $P < 0.005$.

There were no significant main effects or high order interactions in the separate analyses of the passive and active task conditions.

Late positive potential (300 450 and 450 600 ms)

The significant main effect Valence Category, *F*(2,46) 4.0, $P < 0.05$, was qualified by the significant interaction of Task Condition by

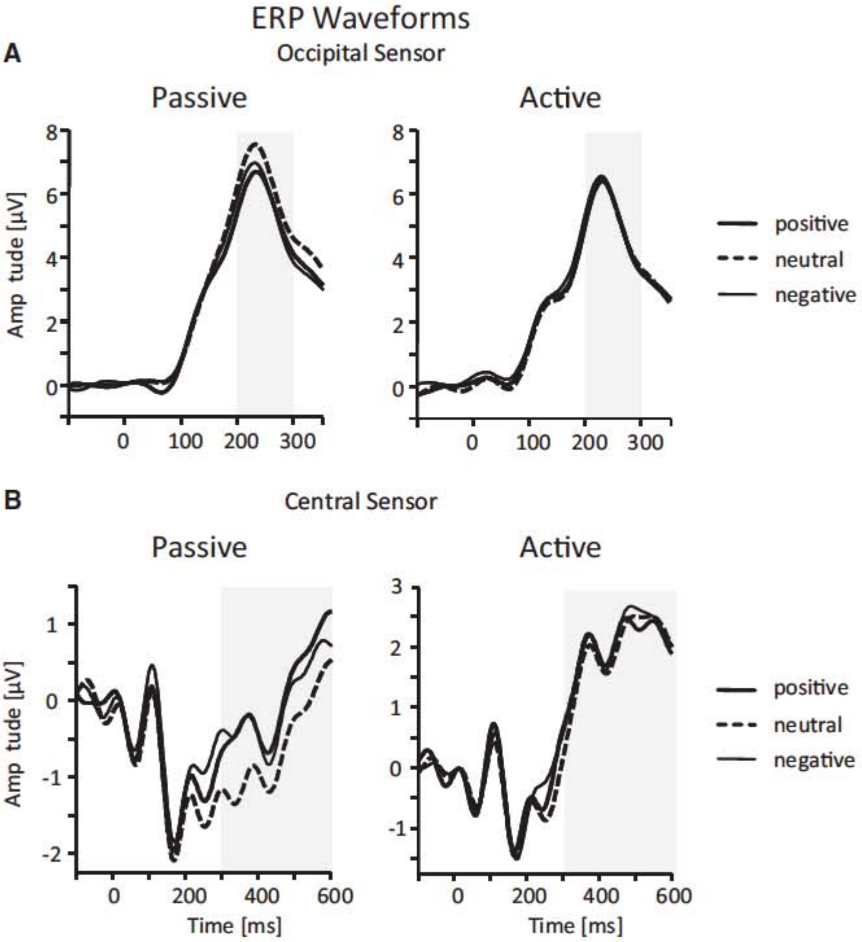

Fig. 2 ERP waveforms for a representative occipital and central sensor illustrate the modulation of the occipital negativity (A) and late positive potential (B) by picture valence during active and passive task conditions.

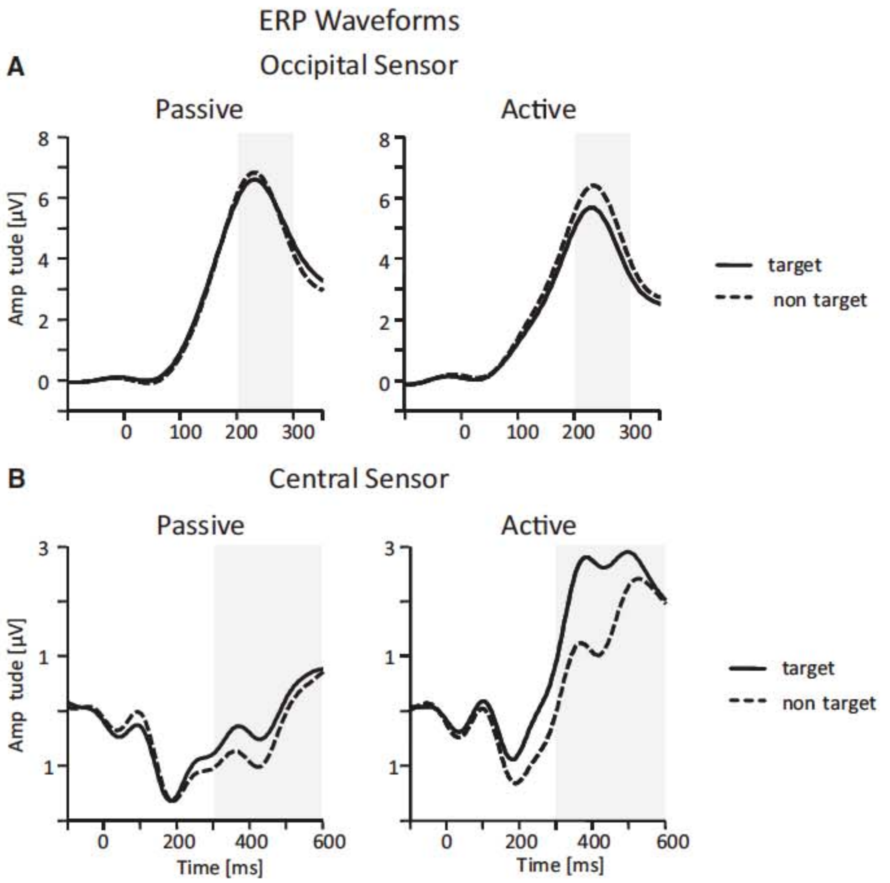

Fig. 3 ERP waveforms for a representative occipital and central sensor illustrate the modulation of the occipital negativity (A) and late positive potential (B) by task relevance during active and passive task conditions.

Valence Category, $F(2,46)$ 3.3, $P<0.05$. To follow up this interaction, separate analysis of the passive viewing and active task conditions was conducted. In the passive viewing condition, a significant main effect of Valence Category was observed, $F(2,46)$ 4.7, $P<0.05$. As in previous research, pleasant and unpleasant pictures elicited a larger LPP as compared with neutral images, $ts(23)$ 2.7 and 2.6, $Ps<0.05$, respectively. Emotional modulation effects were not further qualified by higher order interactions involving factors of Target Category or Time. In contrast, emotional valence of the background pictures did not modulate the LPP in the active categorization condition. The main effect of Valence Category was not significant, $F(2,46)$ 0.04, and the higher order interaction Valence Category × Target Category × Time, $F(2,46)$ 4.4, $P<0.05$, could not be substantiated in a separate follow up analysis based on the factors Target Category or Time.

Significant main effects of Task Condition, $F(1,23)$ 62.6, $P<0.0001$, Target Category, $F(1,23)$ 27.8, $P<0.001$, and Time, $F(1,23)$ 14.4, $P<0.01$, were qualified by the interaction of Task Condition, Target Category and Time, $F(1,23)$ 10.9, $P<0.01$. To follow up this interaction, separate analyses of the earlier and later time windows were conducted. In the earlier time window (300 450 ms), significant main effects of Task $F(1,23)$ 52.6, $P<0.0001$, and Target Category $F(1,23)$ 34.3, $P<0.0001$, were qualified by a significant interaction of Task Condition × Target Category, $F(1,23)$ 15.0, $P<0.005$. Accordingly, both task conditions were analyzed separately. Animal pictures elicited a larger positivity than that of non animal pictures in the active task condition, when the images were task relevant, $F(1,23)$ 39.8, $P<0.0001$, and although less pronounced, also in the passive viewing condition, when the images were not associated with any task, $F(1,23)$ 9.1, $P<0.01$. As expected, a direct comparison of the difference (animal *vs* non animal images) confirmed a significantly larger positive wave in the active as compared with the passive viewing condition, $t(1,23)$ 3.9, $P<0.001$. In the later time window (450 600 ms), significant main effects of Task Condition, $F(1,23)$ 66.0, $P<0.0001$, and Target Category, $F(1,23)$ 11.2, $P<0.01$, were observed, whereas the interaction Task Condition × Target Category was not significant, $F(1,23)$ 1.0. However, exploratory analysis revealed that target effects were sustained in the active categorization condition, Target Category $F(1,23)$ 8.5, $P<0.01$, whereas there was no significant effect in the passive viewing condition, Target Category $F(1,23)$ 3.2, P 0.09.

DISCUSSION

By using a combination of a natural scene categorization task and an emotional picture viewing paradigm, this study showed that directing visual attention toward task relevant stimuli resulted in a loss of sensitivity toward emotional cues in the peripheral visual field. In contrast, in the absence of directed attention to task relevant stimuli, well established effects of selective emotion processing were found, i.e. increased occipital negativity and late positive potential toward emotionally arousing (pleasant and unpleasant) images. These results extend the 'competition for processing' framework for studying emotion attention interactions. Specifically, explicit semantic categorization, a familiar and meaningful task in which participants are experts,

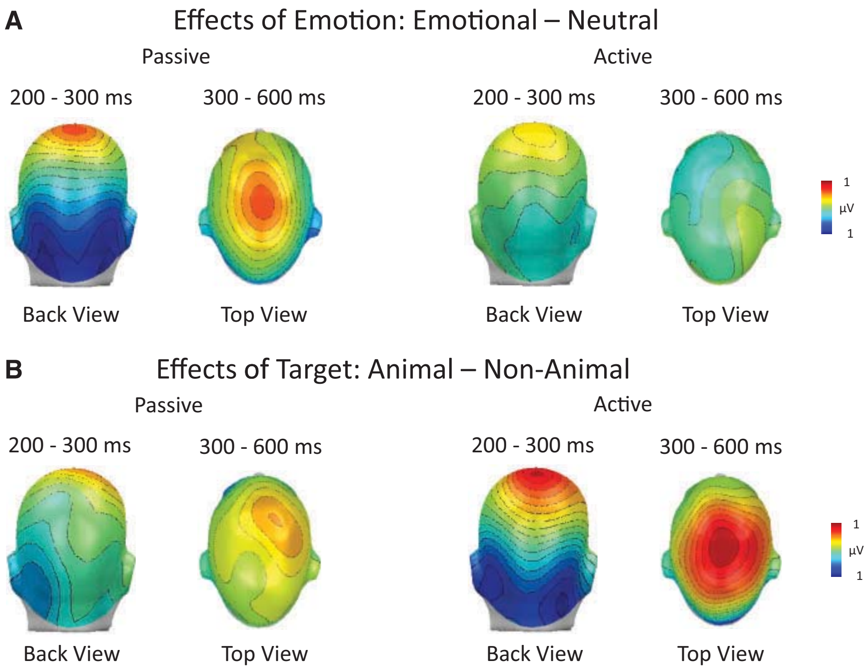

Fig. 4 (A) Illustration of the emotional modulation of the occipital negativity (back view) and the LPP component (top view) during active and passive task conditions. Difference maps ‘emotional neutral’ reveal an emotional modulation during passive viewing but not during the active categorization condition. (B) Illustration of the task modulation of the occipital negativity (back view) and the LPP component (top view) during active and passive task conditions. Difference maps ‘animal non animal’ reveal a pronounced target effect during the active categorization condition and a much less pronounced effect during passive viewing, specifically for the LPP component.

interfered with implicit emotion processing when both processes compete for shared resources.

The ‘competition for processing’ hypothesis provides a framework for the interpretation of task interference effects on emotion processing. Specifically, it is proposed that interference effects occur when the processing demands of concurrent tasks exceed limited processing resources (Pessoa *et al.*, 2002b). Previous studies suggest intramodal competition as a primary source for interference of emotion processing. Specifically, although primary tasks manipulating space based and feature based attention in the visual domain attenuated the preferential emotion processing, as indexed by occipital negativity and LPP (e.g. Holmes *et al.*, 2003; Schupp *et al.*, 2008; De Cesarei *et al.*, 2009; Wiens *et al.*, 2011, 2012), increasing the task load of an auditory task did not systematically suppress the occipital negativity elicited by emotional cues (Schupp *et al.*, 2008). The current findings specify the notion of intramodal competition for processing resources more precisely by focusing on a meaningful and well practiced natural scene categorization task. Natural scene categorization relies on neural representations in higher order visual cortices, and prior research suggests that it is much less dependent on the availability of attentional resources (Li *et al.*, 2002; Rousselet *et al.*, 2002; Fei Fei *et al.*, 2005). This study, however, reveals that the categorization task interferes with preferential emotion processing for emotional background stimuli. A possible explanation for this effect may be that interference results from inter item competition among neural maps representing foreground task stimuli and background emotion stimuli (Franconeri *et al.*, 2013). Specifically, although spontaneous viewing supports the preferential processing of emotional information in the periphery, top down attention processes may focus visual attention on task relevant central stimuli, so that emotionally relevant stimuli no longer elicit the ERP signature of preferential emotion processing. Related to the ‘competition for processing’ perspective in natural scene categorization, interference effects have also been shown for the processing of multiple objects (Rousselet *et al.*, 2004; Walker *et al.*, 2008). Overall, and consistent with the notion for intramodal competition for processing resources, this study demonstrates interference between selective emotion processing and a well practiced and meaningful primary categorization task. Furthermore, the present result may provide the laboratory equivalent of real life examples such as drivers failing to notice pedestrians or other emotionally relevant stimuli when searching for directions (Simons, 2000).

The present results add to previous research on the interaction of emotion and attention in the context of a meaningful and familiar primary task. Specifically, Ferrari *et al.* (2008) employed a semantic categorization task to investigate emotion processing while participants had to decide whether pictures belonged to a specific higher order stimulus category. This study demonstrated that the LPP component is sensitive to picture valence in the context of motor demands and a semantic categorization task unrelated to the emotional content of the pictures. However, despite many shared features, there are crucial differences between these studies. In the study by Ferrari *et al.*, a single picture was presented that belonged to one out of four stimulus categories (humans, animals, landscapes and objects). Of these, the ‘humans’ category contained either pleasant, neutral or unpleasant exemplars. In separate conditions, participants were asked to categorize the images according to whether they belong to either the animal or the human category. Irrespective of whether human pictures were target or non target stimuli, the LPP component was enhanced to emotional compared with neutral human images. Thus, when a single picture is processed, picture valence is encoded spontaneously and irrespective of target status. This study, however, used a different paradigm and observed different results: Task relevance, i.e. attentional focus on the central picture, and emotional processing of the background picture, i.e. outside the focus of attention, were separated by presenting two pictures simultaneously. Under these circumstances, sensitivity to picture valence in the peripheral field is lost and ERP measures sensitive to the perceptual and evaluative stage of processing no longer discriminate between emotional and neutral pictures (Schupp *et al.*, 2006).

A noteworthy aspect of the present finding concerns the timing of visual processing and preferential stimulus processing. Both, target effects in the active task condition as well as emotion effects in the passive viewing condition emerged ~200 ms after stimulus onset, providing an (upper) estimate of when information regarding stimulus category and emotional valence has been extracted. Apparently, preferential stimulus processing builds upon an initial, primarily feedforward sweep of natural scene processing (Thorpe and Fabre Thorpe, 2001). Interestingly, intracranial recordings in the inferior occipital gyrus, fusiform gyrus and inferior temporal cortex revealed robust object selectivity during initial processing (~200 ms), even in the presence of a second object within the image (Agam *et al.*, 2010). Subsequent processing, however, reflected by the early posterior negativity (EPN) and LPP components, seems to be more flexibly regulated, i.e. default prioritization of emotional stimuli or task dependent selection of target objects. Processing in these capacity limited later processing stages, in particular the LPP, seems to be critical for longer lasting stimulus representations and conscious recognition (Chun and Potter, 1995; Sergent *et al.*, 2005; Del Cul *et al.*, 2007). The present results show that the default prioritization of emotion processing is abolished when other stimulus categories are the focus of interest. Specifically, inspection of Figures 2 and 3 suggests a reciprocal relationship of the occipital negativity and late positive potential with regard to the sensitivity to emotion (passive viewing condition) and target (task condition) stimulus significance (see also Wickens *et al.*, 1983). Overall, the 'competition for processing' in a particular processing stage seems to be the key variable accounting for interference effects in the emotion attention interaction (Pessoa *et al.*, 2002).

The current results run counter to previous findings, which suggested that natural scene categorization puts little to no demands on attentional processing resources. This interpretation was based on studies using dual task conditions in which participants performed a central letter discrimination task while they categorized natural scenes in the peripheral field (Li *et al.*, 2002; Fei Fei *et al.*, 2005). The critical issue may regard the operation of attentional control mechanisms (Baluch and Itti, 2011). In explicit dual task conditions, attentional resources should be distributed to facilitate the performance of both task conditions. In contrast, putting implicit and explicit categorization in competition, top down control mechanisms may maximize the allocation of attentional resources toward the task stimuli. This notion, however, would imply that preparatory attentional control mechanisms exert a strong prioritization on perceptual categorization, i.e. facilitating central processing at the expense of peripheral processing in this study.

A high processing demand of the primary task has been deemed critical for interference effects to occur (Luck *et al.*, 2000; Pessoa *et al.*, 2002a). The behavioral data indicate that the categorization task was somewhat more difficult (~80% accuracy) in this study as compared with previous reports (~94% accuracy; Codispoti *et al.*, 2006b). Several methodological variables may account for these differences in performance. Compared with previous studies (Codispoti *et al.*, 2006b), picture size of the task relevant images was reduced, changing physical stimulus parameters. This could possibly make the processing of the stimuli more difficult (Macé *et al.*, 2005), and indeed a reduction in performance has been similarly observed in research creating more demanding processing conditions (e.g. Li *et al.*, 2002; Rousselet *et al.*, 2004). Interestingly, performance of the categorization task (error rate and reaction time) was not affected by the valence of the background pictures. Different results were seen in a previous study in which participants could not rely on top down control to focus attention toward task relevant locations (Muller *et al.*, 2011). In this study, emotional stimuli were discriminated from neutral contents at the neural level and the emotional pictures interfered with task performance in the explicit task (Muller *et al.*, 2011). Both of these studies used short presentation times, thereby preventing saccadic eye movements as a potential alternative explanation for the differing study findings. Thus, top down attention processes may play an important role for the emotion attention interaction and the prioritization of stimulus processing. Corroborating this notion, task instruction had profound effects on the processing of the animal pictures. Specifically, although ERP effects were limited to the task stimuli in the active task, differential LPP amplitudes were seen concurrently for animal (*vs* non animal) and emotional (*vs* neutral) pictures in the passive viewing condition. Taken together, preparatory attentional control mechanisms seem to direct attention toward task relevant locations at the cost of preferential emotion processing at locations outside the focus of attention.

The surprising finding concerns increased LPPs for animal as compared with control stimuli in the passive viewing condition. Similar results have been reported in previous research with pictures of objects and neutral people as a contrasting category (Ferrari *et al.*, 2008). Recent fMRI studies revealed that natural scenes elicit category selective BOLD responses distributed across object selective visual cortical structures irrespective of whether the stimuli were associated with an explicit task or were task irrelevant (Peelen *et al.*, 2009; Walther *et al.*, 2009). In addition, animal stimuli may have a special status among the various stimulus categories of human experience, as behavioral studies show that animal pictures are detected faster and more accurately than inanimate objects, even when controlling for interest, expertise and low level stimulus characteristics (New *et al.*, 2007). Also, single cell recordings in humans revealed the strongest response to animal pictures in the right amygdala (Mormann *et al.*, 2011). Thus, accumulating evidence suggests that the processing of the animal category may be biased toward prioritized processing, presumably reflecting the importance of animals in human evolution (New *et al.*, 2007; Mormann *et al.*, 2011). The current findings extend this notion toward the LPP component, an electrophysiological indicator of selective attention processes.

CONCLUSION

This study examined what happens to peripheral emotional processing when participants simultaneously conducted a meaningful, familiar and natural scene categorization task. Results showed that significant ERP differences between emotional and neutral background images during the passive viewing condition were abolished in the active task condition. These results speak against the notion of an 'automatic' allocation of attention toward emotional stimuli and suggest that emotional stimuli, though privileged, compete for limited processing resources.

REFERENCES

Agam, Y., Liu, H., Papanastassiou, A., et al. (2010). Robust selectivity to two-object images in human visual cortex. *Current Biology*, *20*, 872 9.

Baluch, F., Itti, L. (2011). Mechanisms of top-down attention. *Trends in Neurosciences*, *34*, 210 24.

Bradley, M.M., Codispoti, M., Cuthbert, B.N., Lang, P.J. (2001). Emotion and motivation I: defensive and appetitive reactions in picture processing. *Emotion*, *1*, 276 98.

Bradley, M.M., Lang, P.J. (1994). Measuring emotion: the Self-Assessment Manikin and the Semantic Differential. *Journal of Behavior Therapy and Experimental Psychiatry*, *25*, 49 59.

Christianson, S.A., Loftus, E.F., Hoffman, H., Loftus, G.R. (1991). Eye fixations and memory for emotional events. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *17*, 693 701.

Chun, M.M., Potter, M.C. (1995). A two-stage model for multiple target detection in rapid serial visual presentation. *Journal of Experimental Psychology: Human Perception and Performance*, *21*, 109 27.

Codispoti, M., Cesarei, A.D. (2007). Arousal and attention: picture size and emotional reactions. *Psychophysiology*, *44*, 680 6.

Codispoti, M., Ferrari, V., Cesarei, A.D., Cardinale, R. (2006a). Implicit and explicit categorization of natural scenes. *Progress in Brain Research*, *156*, 53 65.

Codispoti, M., Ferrari, V., Junghofer, M., Schupp, H.T. (2006b). The categorization of natural scenes: brain attention networks revealed by dense sensor ERPs. *NeuroImage*, *32*, 583 91.

Codispoti, M., Mazzetti, M., Bradley, M.M. (2009). Unmasking emotion: exposure duration and emotional engagement. *Psychophysiology*, *46*, 731 8.

De Cesarei, A., Codispoti, M., Schupp, H.T. (2009). Peripheral vision and preferential emotion processing. *Neuroreport*, *20*, 1439 43.

Del Cul, A., Baillet, S., Dehaene, S. (2007). Brain dynamics underlying the nonlinear threshold for access to consciousness. *PLoS Biology*, *5*, e260.

Erthal, F.S., Oliveira, L.D., Mocaiber, I., et al. (2005). Load-dependent modulation of affective picture processing. *Cognitive, Affective & Behavioral Neuroscience*, *5*, 388 95.

Fei-Fei, L., VanRullen, R., Koch, C., Perona, P. (2005). Why does natural scene categorization require little attention? Exploring attentional requirements for natural and synthetic stimuli. *Visual Cognition*, *12*, 893 924.

Ferrari, V., Codispoti, M., Cardinale, R., Bradley, M.M. (2008). Directed and motivated attention during processing of natural scenes. *Journal of Cognitive Neuroscience*, *20*, 1753 61.

Franconeri, S.L., Alvarez, G.A., Cavanagh, P. (2013). Flexible cognitive resources: competitive content maps for attention and memory. *Trends in Cognitive Sciences*, *17*, 134 41.

Herrmann, M.J., Huter, T., Muller, F., et al. (2007). Additive effects of serotonin transporter and tryptophan hydroxylase-2 gene variation on emotional processing. *Cerebral Cortex*, *17*, 1160 3.

Holmes, A., Vuilleumier, P., Eimer, M. (2003). The processing of emotional facial expression is gated by spatial attention: evidence from event-related brain potentials. *Cognitive Brain Research*, *16*, 174 84.

Junghofer, M., Bradley, M.M., Elbert, T.R., Lang, P.J. (2001). Fleeting images: a new look at early emotion discrimination. *Psychophysiology*, *38*, 175 8.

Junghofer, M., Elbert, T., Tucker, D.M., Rockstroh, B. (2000). Statistical control of artifacts in dense array EEG/MEG studies. *Psychophysiology*, *37*, 523 32.

Lang, P.J., Bradley, M.M., Cuthbert, B.N. (1997). Motivated attention: affect, activation, and action. In: Lang, P.J., Simons, R.F., Balaban, M., editors. *Attention and Emotion: Sensory and Motivational Processes*. Mahwah, NJ: Erlbaum.

Lang, P.J., Bradley, M.M., Cuthbert, B.N. (2008). International affective picture system (IAPS): affective ratings of pictures and instruction manual. Technical Report A-8. University of Florida, Gainesville, FL.

Lavie, N. (2005). Distracted and confused? Selective attention under load. *Trends in Cognitive Sciences*, *9*, 75 82.

Li, F.F., VanRullen, R., Koch, C., Perona, P. (2002). Rapid natural scene categorization in the near absence of attention. *Proceedings of the National Academy of Sciences of the United States of America*, *99*, 9596 601.

Luck, S.J., Woodman, G.F., Vogel, E.K. (2000). Event-related potential studies of attention. *Trends in Cognitive Sciences*, *4*, 432 40.

Macé, M.J.-M., Thorpe, S.J., Fabre-Thorpe, M. (2005). Rapid categorization of achromatic natural scenes: how robust at very low contrasts? *European Journal of Neuroscience*, *21*, 2007 18.

Miller, G.A., Gration, G., Yee, C.M. (1988). Generalized implementation of an eye movement correction procedure. *Psychophysiology*, *25*, 241 3.

Mitchell, D.G.V., Nakic, M., Fridberg, D., Kamel, N., Pine, D.S., Blair, R.J.R. (2007). The impact of processing load on emotion. *NeuroImage*, *34*, 1299 309.

Mormann, F., Dubois, J., Kornblith, S., et al. (2011). A category-specific response to animals in the right human amygdala. *Nature Neuroscience*, *14*, 1247 9.

Muller, M.M., Andersen, S.K., Hindi Attar, C. (2011). Attentional bias to briefly presented emotional distractors follows a slow time course in visual cortex. *The Journal of Neuroscience*, *31*, 15914 8.

New, J., Cosmides, L., Tooby, J. (2007). Category-specific attention for animals reflects ancestral priorities, not expertise. *Proceedings of the National Academy of Sciences of the United States of America*, *104*, 16598 603.

Peelen, M.V., Fei-Fei, L., Kastner, S. (2009). Neural mechanisms of rapid natural scene categorization in human visual cortex. *Nature*, *460*, 94 7.

Pessoa, L., Kastner, S., Ungerleider, L.G. (2002). Attentional control of the processing of neutral and emotional stimuli. *Cognitive Brain Research*, *15*, 31 45.

Pessoa, L., McKenna, M., Gutierrez, E., Ungerleider, L.G. (2002). Neural processing of emotional faces requires attention. *Proceedings of the National Academy of Sciences of the United States of America*, *99*, 11458 63.

Peyk, P., Schupp, H.T., Keil, A., Elbert, T., Junghofer, M. (2009). Parallel processing of affective visual stimuli. *Psychophysiology*, *46*, 200 8.

Rousselet, G.A., Fabre-Thorpe, M., Thorpe, S.J. (2002). Parallel processing in high-level categorization of natural images. *Nature Neuroscience*, *5*, 629 30.

Rousselet, G.A., Thorpe, S.J., Fabre-Thorpe, M. (2004). How parallel is visual processing in the ventral pathway? *Trends in Cognitive Sciences*, *8*, 363 70.

Sabatinelli, D., Bradley, M.M., Fitzsimmons, J.R., Lang, P.J. (2005). Parallel amygdala and inferotemporal activation reflect emotional intensity and fear relevance. *NeuroImage*, *24*, 1265 70.

Sabatinelli, D., Keil, A., Frank, D.W., Lang, P.J. (2013). Emotional perception: correspondence of early and late event-related potentials with cortical and subcortical functional MRI. *Biological Psychology*, *92*, 513 9.

Schupp, H.T., Flaisch, T., Stockburger, J., Junghofer, M. (2006). Emotion and attention: event-related brain potential studies. *Progress in Brain Research*, *156*, 31 51.

Schupp, H.T., Junghofer, M., Weike, A.I., Hamm, A.O. (2003). Emotional facilitation of sensory processing in the visual cortex. *Psychological Science*, *14*, 7 13.

Schupp, H.T., Stockburger, J., Bublatzky, F., Junghofer, M., Weike, A.I., Hamm, A.O. (2007a). Explicit attention interferes with selective emotion processing in human extrastriate cortex. *BMC Neuroscience*, *8*, 16.

Schupp, H.T., Stockburger, J., Bublatzky, F., Junghofer, M., Weike, A.I., Hamm, A.O. (2008). The selective processing of emotional visual stimuli while detecting auditory targets: an ERP analysis. *Brain Research*, *1230*, 168 76.

Schupp, H.T., Stockburger, J., Codispoti, M., Junghofer, M., Weike, A.I., Hamm, A.O. (2007b). Selective visual attention to emotion. *The Journal of Neuroscience*, *27*, 1082 9.

Sergent, C., Baillet, S., Dehaene, S. (2005). Timing of the brain events underlying access to consciousness during the attentional blink. *Nature Neuroscience*, *8*, 1391 400.

Simons, D.J. (2000). Attentional capture and inattentional blindness. *Trends in Cognitive Sciences*, *4*, 147 55.

Thorpe, S., Fize, D., Marlot, C. (1996). Speed of processing in the human visual system. *Nature*, *381*, 520 2.

Thorpe, S.J., Fabre-Thorpe, M. (2001). Seeking categories in the brain. *Science*, *291*, 260 3.

Walker, S., Stafford, P., Davis, G. (2008). Ultra-rapid categorization requires visual attention: scenes with multiple foreground objects. *Journal of Vision*, *8*(4), 21, 1 12.

Walther, D.B., Caddigan, E., Fei-Fei, L., Beck, D.M. (2009). Natural scene categories revealed in distributed patterns of activity in the human brain. *The Journal of Neuroscience*, *29*, 10573 81.

Wickens, C., Kramer, A., Vanasse, L., Donchin, E. (1983). Performance of concurrent tasks: a psychophysiological analysis of the reciprocity of information-processing resources. *Science*, *221*, 1080 2.

Wiens, S., Molapour, T., Overfeld, J., Sand, A. (2012). High negative valence does not protect emotional event-related potentials from spatial inattention and perceptual load. *Cognitive, Affective & Behavioral Neuroscience*, *12*, 151 60.

Wiens, S., Sand, A., Olofsson, J.K. (2011). Nonemotional features suppress early and enhance late emotional electrocortical responses to negative pictures. *Biological Psychology*, *86*, 83 9.