Processing of pleasant information can be as fast and strong as unpleasant information: implications for the negativity bias

Ingmar H.A. Franken, Peter Muris, Ilse Nijs and Jan W. van Strien

Several theoretical accounts state that negative or unpleasant information is processed 'faster' and activates more attentional resources than neutral and positive information. This notion is confirmed by several experimental studies. However, these studies did not employ equal values of emotional salience and arousal for positive and negative stimuli. In the present study we examine whether positive stimuli (erotic bodies) are processed as fast and strongly as negative information (mutilated bodies) when equally arousing, biologically relevant stimuli are used. Electrophysiological correlates of the processing of biologically relevant high-arousing emotional stimuli are studied using Event-Related Brain Potentials (ERPs). Results showed that both pleasant and unpleasant stimuli are processed fast and preferentially in the brain, within 100-200 ms after stimulus onset. These studies indicate that, on the electrophysiological level, pleasant stimuli are processed as 'fast and strongly' as unpleasant stimuli if arousal values of the stimuli are high. Implications of these findings for theories of emotion and psychopathology are discussed. *(Netherlands Journal of Psychology,* 64, 168-176.)

Keywords: emotion; negativity bias; ERP; attentional bias; emotional processing

Selective processing of emotional stimuli is a basic feature of our brain which is necessary to signal relevant stimuli in our environment. Once a relevant stimulus has been noticed it can be processed further, and behaviour can be adapted if necessary. The processing of emotional stimuli has been addressed in several studies using behavioural and physiological measures. For example, behavioural studies employing cue-target paradigms (Posner, 1980) show that emotional stimuli are able to capture attention automatically (e.g., Koster, Verschuere, Crombez, & Van Damme, 2005; Mogg & Bradley, 1998). In addition, Event-Related Potential (ERP) studies show that emotional stimuli are processed preferentially above non-emotional stimuli (e.g., Ito, Larsen, Smith, & Cacioppo, 1998; Schupp, Stockburger, Codispoti, Junghofer, Weike, & Hamm, 2007). Further, fMRI studies (Morris, Öhman, & Dolan, 1998) in which fearful stimuli are pre-

Institute of Psychology, Erasmus University Rotterdam
Correspondence to: Ingmar H.A. Franken, Institute of Psychology, Erasmus University Rotterdam, Woudestein T12-35, PO Box 1738, NL 3000 DR Rotterdam, e-mail: franken@fsw.eur.nl
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sented at subliminal levels show that the processing of fearful stimuli in the brain can be executed very quickly. All these results are in line with theories suggesting that emotional stimuli automatically capture attention in a very fast and automatic way (Lang, Bradley, & Cuthbert, 1990; Öhman, 1997; Vuilleumier, 2005). Although there is a general consensus that emotional stimuli are processed preferentially above non-emotional stimuli, there are several important issues that need further investigation.

The first issue, and most relevant for the present study, is that several studies report that negative (unpleasant) stimuli are processed faster and 'stronger' than positive stimuli (pleasant stimuli; Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001) and as such they are thought to have more impact on the brain (Ito et al., 1998), a phenomenon that has been labelled as the negativity bias (Crandall, 1975). From an evolutionary point of view, this makes sense: There must be an evolutionary preparedness for the very fast processing of threat stimuli (LeDoux, 1998; Öhman, 1997). It seems plausible that it would be more important to signal a threatening stimulus immediately (in order to make an avoiding motor reflex; e.g. the fast withdrawal of the foot when a snake is signalled in the woods) than to signal a pleasant stimulus (e.g., a sexual partner or food) very quickly. Although it is extremely important from an evolutionary point of view to signal and respond to pleasant stimuli, in most cases there is no necessity to do this within a fraction of a second.

Several ERP studies that make a comparison between the processing of pleasant versus unpleasant stimuli indeed suggest that the human brain has a selective sensitivity towards negative stimuli above positive and neutral stimuli (Carretie, Mercado, Tapia, & Hinojosa, 2001; Delplanque, Silvert, Hot, Rigoulot, & Sequeira, 2006; Ito et al., 1998; Smith, Cacioppo, Larsen, & Chartrand, 2003; Yuan et al., in press). Similarly, there is also some behavioural research examining the attentional processing of negative stimuli as compared with positive stimuli. For example, Pratto and John (1991) employed an emotional Stroop paradigm that included negative as well as positive words. In keeping with the above-described ERP studies, the results demonstrated an attentional bias for negative words, but no such effect for positive stimuli. Although all these studies seem to indicate that negative stimuli have more impact on the brain than positive stimuli, there are several caveats that should be studied in more detail before this notion can be generalised. First of all, it can be argued that prioritised processing of negative stimuli is primarily due to the typically low arousal levels that are associated with positive cues. Interestingly, Tipples and Sharma (2000) used a dot probe task to investigate attentional bias for affective stimuli and demonstrated that high-arousing pleasant stimuli do result in an attentional bias, which resembles the enhanced processing phenomenon as observed for negative, unpleasant stimuli. To summarise, most studies documenting the enhanced processing of negative relative to positive stimuli only use unpleasant stimuli and have not taken arousal levels of various stimuli into account. This research may typically have employed stimuli with low arousability features, which might explain the finding of the negativity-bias effect.

Further, it should be noted that the pleasant stimuli as used in previous research possess different contents to the pleasant stimuli that are typically employed. More precisely, whereas negative stimuli mainly consisted of biologically relevant threat pictures (attack situations, mutilations), positive stimuli seem to represent less biologically relevant themes (rollercoaster, sport cars or flowers). As there is clear evidence that biologically relevant stimuli result in enhanced neurophysiological processing and attentional biases in healthy subjects, and are differentially processed in distinct neural networks as compared with non-biologically relevant stimuli (Anokhin, Golosheykin, Sirevaag, Kristjansson, Rohrbaugh, & Heath, 2006), it seems important to take this feature into account in studies comparing the processing of negative and positive stimuli.

The second issue pertains to the question whether the selective processing of emotional stimuli is only a feature of clinical patients or whether it is also present in normal populations. Of course, attentional biases are a hallmark of anxiety psychopathology, and there are many studies showing that patients with an anxiety disorder such as spider phobia, social phobia or post-traumatic stress disorder display a preferential processing of threat-related stimuli (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van Ijzendoorn, 2007; McNally, 1998). However, there is also research suggesting the presence of a processing bias in healthy subjects, but only in persons displaying high levels of trait anxiety (Koster et al., 2005). In contrast, when looking at research that goes beyond behavioural measures, such as ERP and fMRI studies, it becomes clear that an enhanced processing of emotional stimuli is a common feature which is also present in healthy subjects.

In the present study we employed high-arousing pleasant stimuli (erotic bodies) and high-arousing negative stimuli (mutilated bodies), with both having biological relevance in order to keep aspects beyond valence as similar as possible. Note that these two categories have similar physical properties, both categories display humans in a social setting and display simple perceptual features: bodies or parts of bodies. Electrophysiological (ERP) indices will be employed in a population of healthy individuals to investigate the processing of pleasant and unpleasant stimuli.

ERPs are particularly suited to study the temporal characteristics of the selective processing and may reveal differences at various stages between emotional and neutral stimuli. In addition, because there is information on the localisation of specific ERP components, this methodology provides us with information on neural correlates associated with biased processing. In the present study we will investigate early stages of processing using the Early Posterior Negativity (EPN) component. It is known that emotional stimuli yield a negative-going potential at posterior regions starting 100-300 ms (EPN) after stimulus onset (reduced positivity), which is thought to originate from the extra-striate cortex (Pourtois, Thut, Grave de Peralta, Michel, & Vuilleumier, 2005; Schupp, Stockburger, Bublatzky et al., 2007). This EPN represents the perceptual encoding phase at which stimuli are selected for enhanced processing (Schupp, Stockburger, Codispoti et al., 2007). Later stages of stimulus processing are measured using the Late Positive Potential (LPP) which is a P3-like wave capturing the elaborative stimulus evaluation. This index of processing emerges 300-400 ms after stimulus onset and can stay present for several seconds (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000). Several studies show that both early and late ERP components can be modulated by attentional demands (Schupp, Stockburger, Codispoti et al., 2007). Research addressing the neural origin of this enhanced positive slow wave shows that it represents activity in a network of visual cortical structures such as the lateral occipital, inferotemporal, and parietal visual areas (Sabatinelli, Lang, Keil, & Bradley, 2007).

The main goal of the present study was to investigate whether pleasant and unpleasant information is processed in similar ways, on perceptual and elaborative processing levels. For this purpose, non-clinical subjects were exposed to high-arousing, biologically relevant positive and negative stimuli as well as neutral stimuli. It was expected that both negative and positive stimuli would be processed preferentially as compared with neutral stimuli.

Methods

Participants

Participants were 41 undergraduate students (25 females) from Erasmus University Rotterdam. The average age was 20.3 years ($SD = 3.1$). The participants received course credits for their participation.

Stimuli and experimental paradigm

Sixty colour pictures (20 neutral, 20 high-arousing pleasant, and 20 high-arousing unpleasant slides[1]) were selected from the IAPS (Lang, Bradley, & Cuthbert, 1999). Neutral pictures consisted mainly of household objects, unpleasant pictures consisted of mutilated bodies, and pleasant pictures consisted of erotic couples. Pleasant and unpleasant stimuli were selected on the basis of standardised valence and arousal ratings (Lang, Bradley, & Cuthbert, 1999). According to the normative data, mean arousal ratings of the neutral, pleasant and unpleasant stimuli were 2.4 ($SD = 0.48$), 6.4 ($SD = 0.36$) and 6.5 ($SD = 0.59$), respectively. An ANOVA demonstrated significant differences between the arousal ratings for each category, $F = 452.4$, $p < 0.001$. Bonferroni post-hoc tests indicated that there were no significant differences between the arousal ratings for the pleasant and unpleasant pictures ($p = 1.0$). As expected, both pleasant and unpleasant pictures yielded higher arousal ratings than neutral pictures ($p < 0.001$). Mean valence ratings of the neutral, pleasant, and unpleasant stimuli were 5.0 ($SD = 0.25$), 6.8 ($SD = 0.33$) and 1.7 ($SD = 0.31$) respectively. An ANOVA also revealed significant differences between the valence ratings for each category $F = 1487.6$, $p < 0.001$. As expected, pleasant pictures had higher valence scores than neutral pictures ($p < 0.001$), which in turn had higher valence scores than unpleasant pictures ($p < 0.001$). All pictures were presented for 1500 ms in blocks of five pictures per stimulus category, occupying about 5° of horizontal visual angle. Each block was presented twice, resulting in 120 stimulus presentations. Blocks were presented semi-randomly, with the restriction that no blocks of the same category were presented subsequently. The inter-stimulus interval was 2500 ms.

Procedure

Upon arrival, participants were instructed about the procedure and signed informed consent. After this, participants filled out the questionnaires. Subsequently, subjects were seated in a comfortable chair in a light- and sound-attenuated room. First, participants conducted a cognitive decision-making task (10 minutes; not reported in this paper). Then they performed the IAPS picture task. Stimuli were presented on a 21″ monitor 1.5 metres away from the participant. Participants were instructed to pay close attention to the pictures that would be presented. To be sure that they paid attention to the pictures they were told that questions about the pictures could be asked after the experiment. Approval was obtained from the local ethics

1 *The IAPS pictures were: Neutral: 7175, 7010, 7004, 7020, 7950, 7040, 7000, 7150, 7080, 7006, 7491, 7090, 7110, 7031, 7100, 7217, 5740, 7035, 7096, 7050; Pleasant: 4650, 4660, 4680, 4687, 4689, 4690, 4607, 4608, 4611, 4653, 4656, 4658, 4659, 4670, 4681, 4810, 4672, 4666, 4652, 4800; Unpleasant: 3000, 3010, 3030, 3051, 3060, 3061, 3062, 3063, 3064, 3071, 3080, 3130, 3150, 3168, 9253, 3100, 3102, 3110,3053, 3120.*

committee of the Institute of Psychology and the experiment was in accordance with international ethical guidelines.

Electroencephalographic (EEG) recording and signal processing

ERPs were recorded by means of a Biosemi Active-Two amplifier system from 64 scalp sites (10-20 system) using Ag/AgCl electrodes (active electrodes) mounted in an elastic cap. In addition, six additional electrodes were attached to the left and right mastoids, the two outer canthi of both eyes (HEOG), and the infraorbital and supraorbital regions of the eye (VEOG). Online signals were recorded with a low pass filter of 134 Hz. All signals were digitised with a sample rate of 512 Hz and 24-bit A/D conversion. Data were re-referenced off-line to an average reference. EEG and EOG activity was filtered off-line with a bandpass of 0.01-30 Hz (phase shift-free Butterworth filters; 24dB/octave slope). Data were segmented in epochs of 1300 ms (200 ms before and 1100 ms after response). After ocular correction (Gratton, Coles, & Donchin, 1983), epochs including an EEG signal exceeding ± 75 µV were excluded from the average. The mean 200 ms period before the stimulus presentation served as baseline. After baseline correction, average ERP waves were calculated for the neutral, pleasant and unpleasant stimulus conditions. The resulting ERP waves were visually inspected and appeared to correspond well with ERP waves usually reported in response to visual emotional stimuli (see Figures 1A and 2A). The mean number of artifact-free segments for the neutral, pleasant and unpleasant conditions was 29.3, 31.0, and 30.9 respectively (minimum = 18). Mean activity of the EPN (100-300 ms time window), and the LPP (400-1000 ms time window) were used as measures of early and late emotional processing, respectively. For the EPN, the effects were most pronounced at the O1 and O2 electrodes, and for the LPP at CPz1 and CPz2. This is in accordance with previous research (Schupp, Junghoefer, Weike, & Hamm, 2003b, 2004), and consequently these electrodes were selected for the statistical analysis.

Data analysis

First, we examined differences in emotional processing of the stimuli for each component (i.e., EPN and LPP) by means of a 3 (Emotion: neutral vs. pleasant vs. unpleasant) x 2 (Hemisphere: left vs. right) x 2 (Time window: early vs. late) repeated measures ANOVA. For the EPN the early time window was 100-200 ms and the late one was 200-300 ms (Figure 1B). For the LPP, the early time window was 400-700 and the late one was 700-1000 ms (Figure 2B). Significant effects were further analysed using Bonferroni-corrected post-hoc *t*-tests. Because we were only interested in Emotion-relevant interaction effects, we only report effects that included this factor.

Results

EPN

A main effect of Emotion was observed, $F(2, 80) = 32.6$, $p < 0.001$. Post-hoc tests revealed that pleasant ($M = 4.2$) and unpleasant stimuli ($M = 5.1$) yielded smaller (= larger EPN) amplitudes as compared with neutral stimuli ($M = 6.6$, both *p*s < 0.001). Furthermore, pleasant stimuli yielded larger EPN amplitudes as compared with unpleasant stimuli ($p < 0.05$). A significant interaction effect of Emotion x Time was also observed $F(2, 80) = 30.1$, $p < 0.001$. Post-hoc tests showed that during the first EPN time window (100-200 ms) there was a difference (neutral > emotional; suggesting a larger EPN for emotional stimuli) between neutral versus pleasant stimuli ($p < 0.001$), and a difference between neutral versus unpleasant ($p < 0.001$), with no difference between responses to pleasant and unpleasant stimuli. However, during the second time window (200-300 ms) pleasant stimuli yielded larger EPN amplitudes as compared with unpleasant stimuli ($p < 0.001$; see Figure 1B). In addition, an Emotion x Hemisphere x Time effect emerged, $F(2, 80) = 4.1$, $p < 0.05$. This effect was similar (for both hemispheres) to the Emotion x Time effect as described above, the only difference was that in the first time window (100-200 ms) unpleasant stimuli yielded larger EPN amplitudes as compared with neutral stimuli in the left hemisphere ($p < 0.001$), this effect was not present in the right hemisphere.

LPP

For the LPP, a main effect of Emotion was observed, $F(2, 80) = 69.1$, $p < 0.001$. Post-hoc tests revealed that pleasant ($M = 5.9$, $p < 0.001$) and unpleasant stimuli ($M = 5.5$, $p < 0.001$) yielded larger LPP amplitudes as compared with neutral stimuli ($M = 2.5$). No difference was observed between pleasant and unpleasant stimuli. In addition, an Emotion x Time interaction effect was observed $F(2, 80) = 5.5$, $p < 0.01$. However, post-hoc tests did not reveal a significant effect of time over and above the above-described effect of Emotion. Accordingly, the Emotion x Time effect of the LPP will not be discussed further.

Discussion

As expected, this study demonstrated that, in an early stage (100-300 ms), pleasant and unpleasant information is preferentially processed over neutral information. Moreover, pleasant stimuli yielded an enhanced EPN as compared with unpleasant stimuli in the second part of this stage

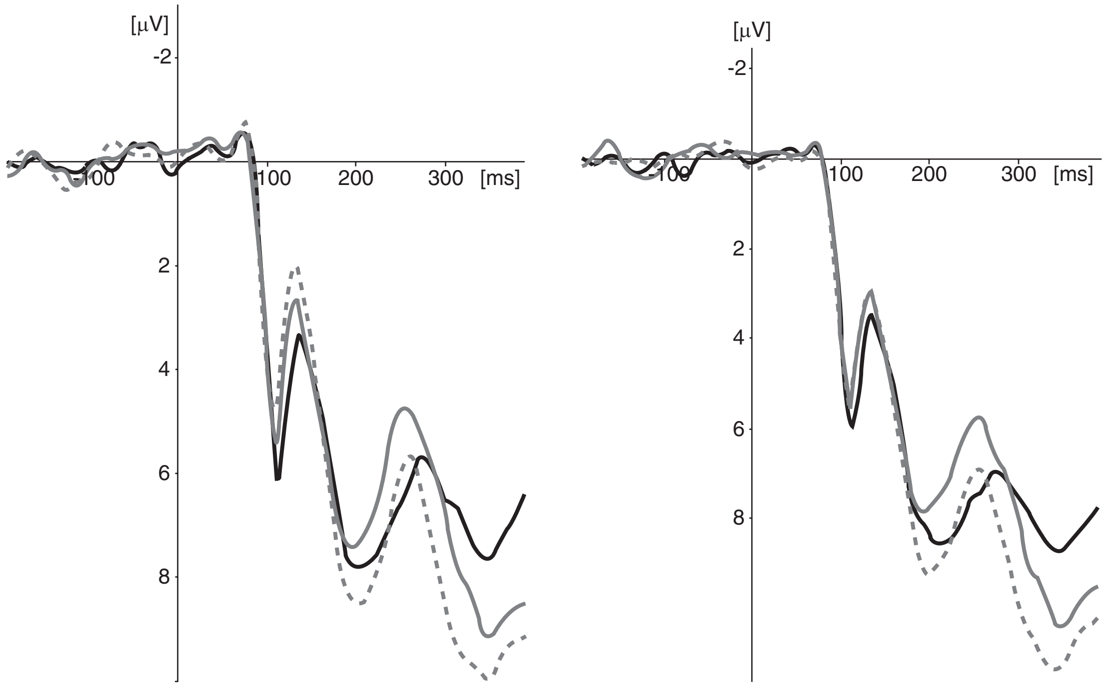

Figure 1A
EPN (100-300 ms) waves to neutral (black lines), pleasant (solid grey lines) and unpleasant pictures (dashed grey lines) at O1 (left panel) and O2 (right panel).

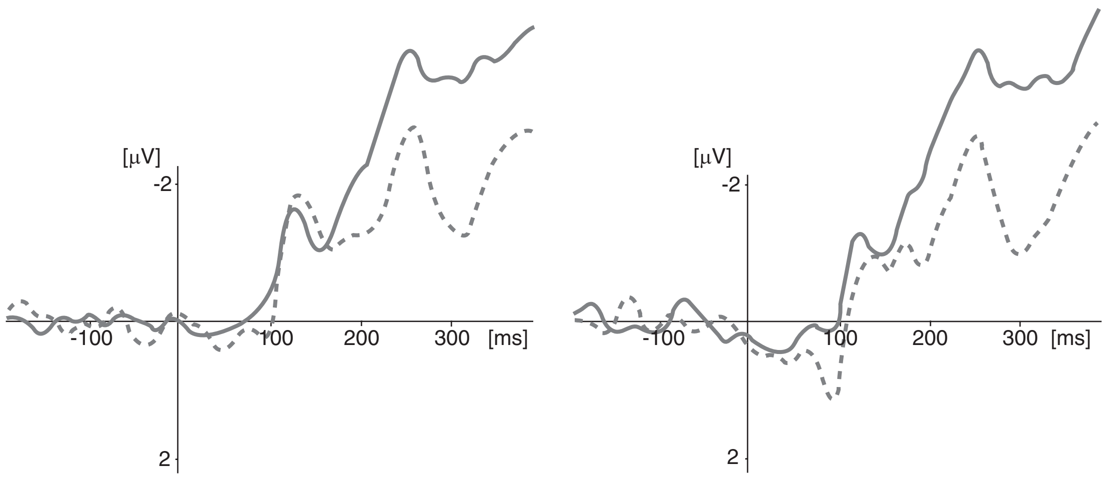

Figure 1B
EPN difference waves (emotional – neutral) to pleasant (solid grey lines) and unpleasant pictures (dashed grey lines) at O1 (left panel) and O2 (right panel).

(200-300 ms), suggesting that in this stage there is even a preferential processing of high arousing pleasant stimuli above high arousing unpleasant stimuli. Note that this difference is not the result of differences in arousability of the stimuli. According to the normative data of the IAPS, unpleasant and pleasant pictures had similar arousal ratings. As the EPN represents the perceptual encoding phase at which stimuli are selected for further processing, this result suggests that both high arousing pleasant and high arousing unpleasant information yields enhanced perceptual encoding and selection.

Further, analysis of the later ERP component, the LPP, revealed that pleasant and unpleasant information are preferentially processed above neutral information. As the LPP represents an elaborative stimulus evaluation, the results suggest that both high arousing pleasant and high arousing unpleasant stimuli are more extensively evaluated than neutral stimuli. This has been observed in several other studies (e.g., Schupp, Cuthbert, Bradley, Hillman, Hamm & Lang, 2004). Most importantly, the LPP to unpleasant pictures was not different from the LPP to pleasant pictures. This is not in keeping with the negativity bias theory which suggests that unpleasant stimuli have more impact on the brain than pleasant stimuli.

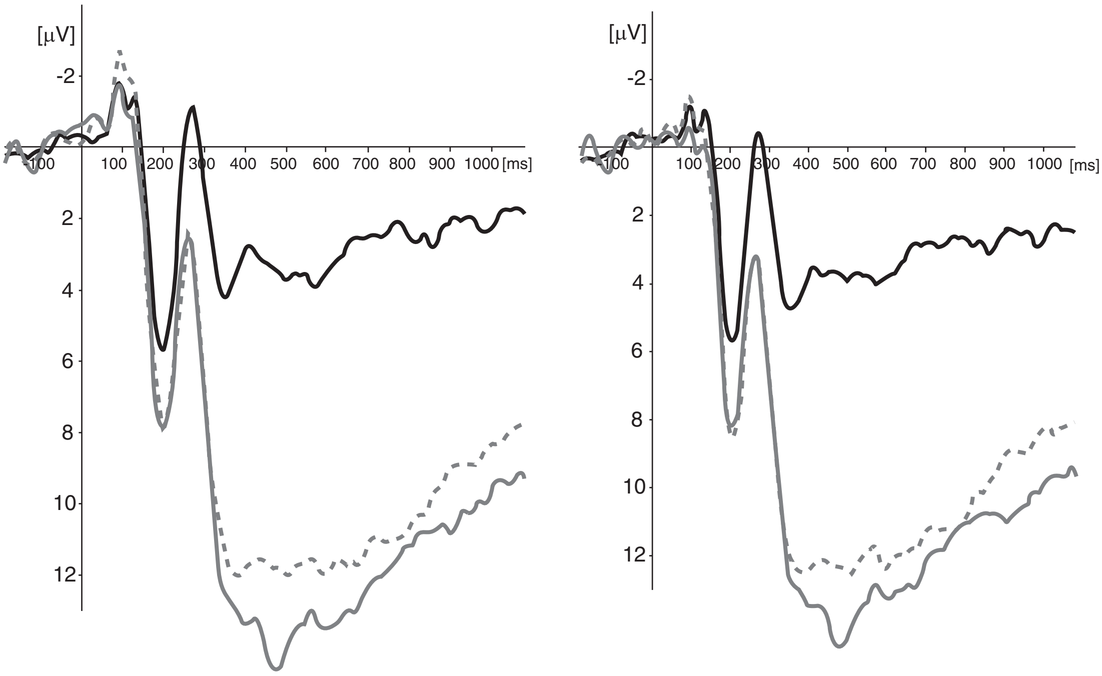

Figure 2A
LPP (400-1000 ms) waves to neutral (black lines), pleasant (solid grey lines) and unpleasant pictures (dashed grey lines) at CP1 (left panel) and CP2 (right panel).

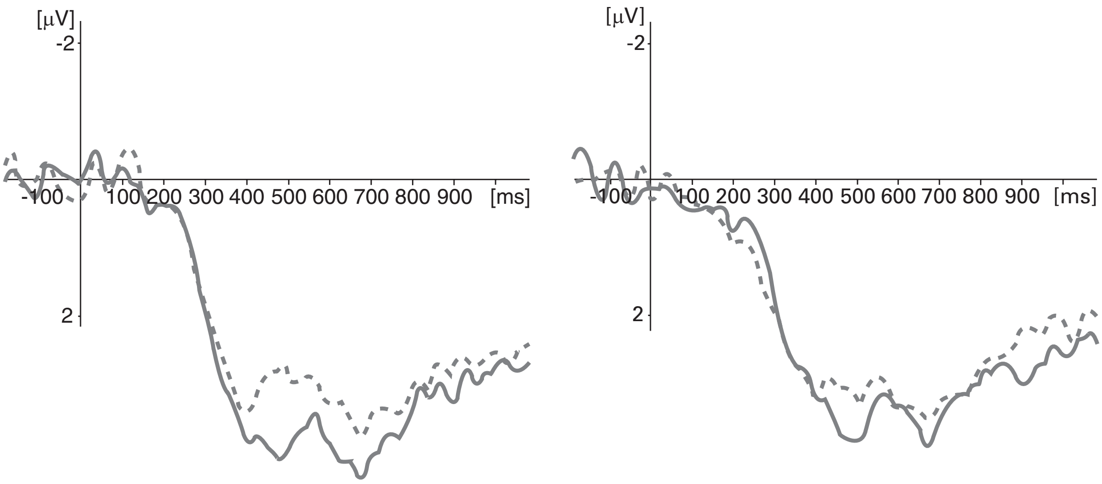

Figure 2B
LPP difference waves (emotional – neutral) to pleasant (solid grey lines) and unpleasant pictures (dashed grey lines) at CP1 (left panel) and CP2 (right panel).

This study suggests that during the early perceptual and attentional stages of processing, there is no preferential processing of negative information over positive information when one controls for arousal levels and biological relevance of the stimuli. As such, we did not find evidence for the 'negativity bias' notion which suggests that there is an evolutionary evolved mechanism in the human brain facilitating a rapid and intense response to aversive events. Instead, the present research suggests that high arousing pleasant and high arousing unpleasant information has equal impact on stimulus processing. Note that we do not suggest that there is no negativity bias in other psychological functions. We only demonstrated that the processing of high arousing pleasant information in the human brain at an initial, basic level is not different from the processing of high arousing unpleasant information. It might be that during later stages of processing, negative information is preferentially processed above positive information; for example, a recent study by Hajcak and Olvet (2008) found that at later stages of processes (>1000 ms) there was a persistence of increased attention (enhanced LPPs) after unpleasant compared with pleasant stimuli which is consistent with the existence of a negativity bias at later stages. Further, the present findings do not rule out the possibility for the presence of a negativity bias for low arousing stimuli.

Several studies have shown that one important neuroanatomical substrate of fast perceptual and attentional processing is the amygdala. There is strong support for the notion that the amygdala is involved in the affective enhancement of activation in the visual cortex (Vuilleumier, 2005; Vuilleumier & Driver, 2007). The present results are in line with the idea that the amygdala is involved in the processing of salient information, either positive or negative (Sander, Grafman, & Zalla, 2003). Several studies have demonstrated that the amygdala is involved in the processing of both unpleasant and pleasant information. Furthermore, the present results are in concordance with appraisal theories of emotion (e.g., Lazarus, 1991) which suggest a quick mechanism in which the brain distinguishes between neutral and emotional information, regardless of whether this information is positive or negative, and devotes more attentional resources to emotionally relevant information.

The present findings are also in concordance with previous studies using biologically relevant stimuli such as erotic and mutilated bodies (Schupp, Junghoefer, Weike, & Hamm, 2003a; Schupp, Stockburger, Codispoti et al., 2007). In these studies it was found that the early posterior ERP activity (the EPN component) was more pronounced for erotica than for mutilated bodies. In the later stage (LPP) Schupp et al. did not observe ERP differences between arousing pleasant and unpleasant stimuli, which is in agreement with the present findings. The observation that high-arousing pleasant stimuli elicit an early differential ERP activity which is larger than unpleasant stimuli is in contrast with the 'negativity bias' theories and as such undermines the notion that negative information is processed faster. Early posterior electrophysiological activity beginning 100 ms after stimulus presentation represents perceptual processing (VanRullen & Thorpe, 2001; Vuilleumier, 2005) and originates in the extrastriate cortex (Schupp, Stockburger, Bublatzky et al., 2007). It must be noted that the possibility cannot be ruled out that negative information such as subliminally presented fearful faces differentially activate neural structures even earlier (<100 ms) in the time course of visual processing (e.g., the amygdala, Morris et al., 1998; Vuilleumier, Richardson, Armony, Driver, & Dolan, 2004). To our knowledge, there have been no studies on whether high-arousing pleasant stimuli are also able to influence these very early (<100 ms) brain responses. Whether this is true for positive information awaits further research.

Concerning the lateralisation of the emotional processing, we observed largely the same results for left and right hemisphere. There was one exception, unpleasant stimuli yielded smaller amplitudes (= larger EPN) as compared with neutral stimuli in the left hemisphere. This effect was not present in the right hemisphere. This finding is difficult to explain since it has not been reported before as far as we know, and should be interpreted with caution since we also found an overall effect over both left and right hemisphere. The effect that was found in the left hemisphere just failed to reach significance in the right hemisphere. Therefore, we suggest that this finding needs replication before drawing firm conclusions.

The present finding that both pleasant and unpleasant stimuli are preferentially processed above neutral stimuli is also in line with studies that examined emotion processing at later processing stages (i.e. motor output systems). Using transcranial magnetic stimulation (TMS) and electromyography (EMG), Hajcak, Molnar, George, Bolger, Koola, & Nahas (2007) showed that viewing arousing stimuli, regardless of valence, increased motor cortex excitability. Also using TMS, Baumgartner and colleagues (2007) found no differences between Motor Evoked Potentials (MEPs) obtained during the presentation of emotional stimuli of different valence.

The present study has several limitations. First, we did not obtain self-reported valance and arousal values for the IAPS pictures. It might be that the self-reported ratings differ from the normative IAPS ratings. Although there might be some variation between self-reported data and normative data, it is unlikely that there are large differences between these two measures. Second we used only two categories of biological relevance: erotic and mutilated bodies. Other biologically relevant stimuli (e.g., social nonverbal communication, responding of others to threat cues) might be less straightforward than the stimuli we employed. Therefore, the results cannot be generalised to all biologically relevant stimuli. Third, it cannot be ruled out that the ERP findings are the result of differences in physical stimulus properties such as luminance differences or differences in colour; in particular the EPN is sensitive for these differences (Schupp, Flaisch, Stockburger, & Junghofer, 2006). However, we tried to keep the physical stimulus properties of pleasant and unpleasant stimuli as similar as possible by using human bodies on both occasions. Further, it is likely that small differences in physical stimulus properties such as luminance are randomly distributed in each category. Fourth, although it was not a goal of the present study, we were not able to examine gender differences because of the relatively low proportion of males in our sample. It is known that there are gender differences in emotional processing, and it would be interesting to examine these differences in future studies.

Overall, the results are in line with theories posing that individuals automatically pay attention to emotional stimuli, regardless of the valence of these stimuli (Lang, Bradley, & Cuthbert, 1990, 1997). This has implications for categorical explanations of psychopathology which state that an attentional bias is specific for clinical populations and threatening cues (Bar-Haim et al., 2007). All studies so far that employed high-arousing pleasant stimuli did show early processing preference of the brain for this category of stimuli. This suggests that attentional processing is a function of arousal properties of the stimulus and trait levels of emotional functioning of the subject.

References

Anokhin, A. P., Golosheykin, S., Sirevaag, E., Kristjansson, S., Rohrbaugh, J. W., & Heath, A. C. (2006). Rapid discrimination of visual scene content in the human brain. *Brain Research, 1093*, 167-177.

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & van Ijzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: A meta-analytic study. *Psychological Bulletin, 133*, 1-24.

Baumeister, R. F., Bratslavsky, E., Finkenauer, C., & Vohs, K. D. (2001). Bad is stronger than good. *Review of General Psychology, 5*, 323-370.

Baumgartner, T., Willi, M., & Jancke, L. (2007). Modulation of corticospinal activity by strong emotions evoked by pictures and classical music: a transcranial magnetic stimulation study. *Neuroreport, 18*, 261-265.

Carretie, L., Mercado, F., Tapia, M., & Hinojosa, J. A. (2001). Emotion, attention, and the 'negativity bias', studied through event-related potentials. *International Journal of Psychophysiology, 41*, 75-85.

Crandall, J. E. (1975). 'Negativity bias' in evaluative ratings. *Journal of Social Psychology, 95*, 109-116.

Cuthbert, B. N., Schupp, H. T., Bradley, M. M., Birbaumer, N., & Lang, P. J. (2000). Brain potentials in affective picture processing: covariation with autonomic arousal and affective report. *Biological Psychology, 52*, 95-111.

Delplanque, S., Silvert, L., Hot, P., Rigoulot, S., & Sequeira, H. (2006). Arousal and valence effects on event-related P3a and P3b during emotional categorization. *International Journal of Psychophysiology, 60*, 315-322.

Gratton, G., Coles, M. G. H., & Donchin, E. (1983). A new method for off-line removal of ocular artifact. *Electroencephalography and Clinical Neurophysiology, 55*, 468-484.

Hajcak, G., Molnar, C., George, M. S., Bolger, K., Koola, J., & Nahas, Z. (2007). Emotion facilitates action: a transcranial magnetic stimulation study of motor cortex excitability during picture viewing. *Psychophysiology, 44*, 91-97.

Hajcak, G., & Olvet, D. M. (2008). The persistence of attention to emotion: brain potentials during and after picture presentation. *Emotion, 8*, 250-255.

Ito, T. A., Larsen, J. T., Smith, N. K., & Cacioppo, J. T. (1998). Negative information weighs more heavily on the brain: the negativity bias in evaluative categorizations. *Journal of Personality and Social Psychology, 75*, 887-900.

Koster, E. H., Verschuere, B., Crombez, G., & Van Damme, S. (2005). Time-course of attention for threatening pictures in high and low trait anxiety. *Behaviour research and therapy, 43*, 1087-1098.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1990). Emotion, attention, and the startle reflex. *Psychological Review, 97*, 377-395.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1997). Motivated attention: Affect, activation, and action. In P. J. Lang, R. F. Simons & M. Balaban (editors), *Attention and orienting: sensory and motivational processes* (pp. 97-136). New Jersey: Lawrence Erlbaum Associates Inc.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1999). *International affective picture system (IAPS): Instruction Manual and Affective Ratings*. Gainsville, FL: The Center for Research in Psychophysiology, University of Florida.

Lazarus, R. S. (1991). *Emotion and adaptation*. New York, NY: Oxford University Press.

LeDoux, J. (1998). Fear and the brain: Where have we been, and where are we going? *Biological Psychiatry, 44*, 1229-1238.

McNally, R. J. (1998). Information-processing abnormalities in anxiety disorders - implications for cognitive neuroscience. *Cognition and Emotion, 12*, 479-495.

Mogg, K., & Bradley, B. P. (1998). A cognitive-motivational analysis of anxiety. *Behaviour Research and Therapy, 36*, 809-848.

Morris, J. S., Öhman, A., & Dolan, R. J. (1998). Conscious and unconscious emotional learning in the human amygdala. *Nature, 393*, 467-470.

Öhman, A. (1997). As fast as the blink of an eye: Evolutionary prepardness for preattentive processing of threat. In P. J. Lang, R. F. Simons & M. Balaban (editors.), *Attention and orienting: sensory and motivational processes* (pp. 477). New Jersey: Lawrence Erlbaum Associates Inc.

Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology, 32*, 3-25.

Pourtois, G., Thut, G., Grave de Peralta, R., Michel, C., & Vuilleumier, P. (2005). Two electrophysiological stages of spatial orienting towards fearful faces: early temporo-parietal activation preceding gain control in extrastriate visual cortex. *NeuroImage, 26*, 149-163.

Pratto, F., & John, O. P. (1991). Automatic vigilance: the attention-grabbing power of negative social information. *Journal of Personality and Social Psychology, 61*, 380-391.

Sabatinelli, D., Lang, P. J., Keil, A., & Bradley, M. M. (2007). Emotional perception: correlation of functional MRI and event-related potentials. *Cerebral Cortex, 17*, 1085-1091.

Sander, D., Grafman, J., & Zalla, T. (2003). The human amygdala: an evolved system for relevance detection. *Reviews in the Neurosciences, 14*, 303-316.

Schupp, H., Cuthbert, B. N., Bradley, M. M., Hillman, C. H., Hamm, A. O., & Lang, P. J. (2004). Brain processes in emotional perception: Motivated attention. *Cognition and Emotion, 18*, 593-611.

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., Junghoefer, M., Weike, A. I., & Hamm, A. O. (2003a). Attention and emotion: an ERP analysis of facilitated emotional stimulus processing. *Neuroreport, 14*, 1107-1110.

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

Schupp, H. T., Junghoefer, M., Weike, A. I., & Hamm, A. O. (2004). The selective processing of briefly presented affective pictures: An ERP analysis. *Psychophysiology, 41*, 441-449.

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

Schupp, H. T., Stockburger, J., Codispoti, M., Junghofer, M., Weike, A. I., & Hamm, A. O. (2007). Selective visual attention to emotion. *Journal of Neuroscience, 27*, 1082-1089.

Smith, N. K., Cacioppo, J. T., Larsen, J. T., & Chartrand, T. L. (2003). May I have your attention, please: Electrocortical responses to positive and negative stimuli. *Neuropsychologia, 41*, 171-183.

Tipples, J., & Sharma, D. (2000). Orienting to exogenous cues and attentional bias to affective pictures reflect separate processes. *British Journal of Psychology, 91*, 87-97.

VanRullen, R., & Thorpe, S. J. (2001). The time course of visual processing: from early perception to decision-making. *Journal of Cognitive Neuroscience, 13*, 454-461.

Vuilleumier, P. (2005). How brains beware: neural mechanisms of emotional attention. *Trends in Cognitive Science, 9*, 585-594.

Vuilleumier, P., & Driver, J. (2007). Modulation of visual processing by attention and emotion: windows on causal interactions between human brain regions. *Philosophical Transactions of the Royal Society B: Biological Sciences, 362*, 837-855.

Vuilleumier, P., Richardson, M. P., Armony, J. L., Driver, J., & Dolan, R. J. (2004). Distant influences of amygdala lesion on visual cortical activation during emotional face processing. *Nature Neuroscience, 7*, 1271-1278.

Yuan, J., Zhang, Q., Chen, A., Li, H., Wang, Q., Zhuang, Z., et al. (in press). Are we sensitive to valence differences in emotionally negative stimuli? Electrophysiological evidence from an ERP study. *Neuropsychologia*.