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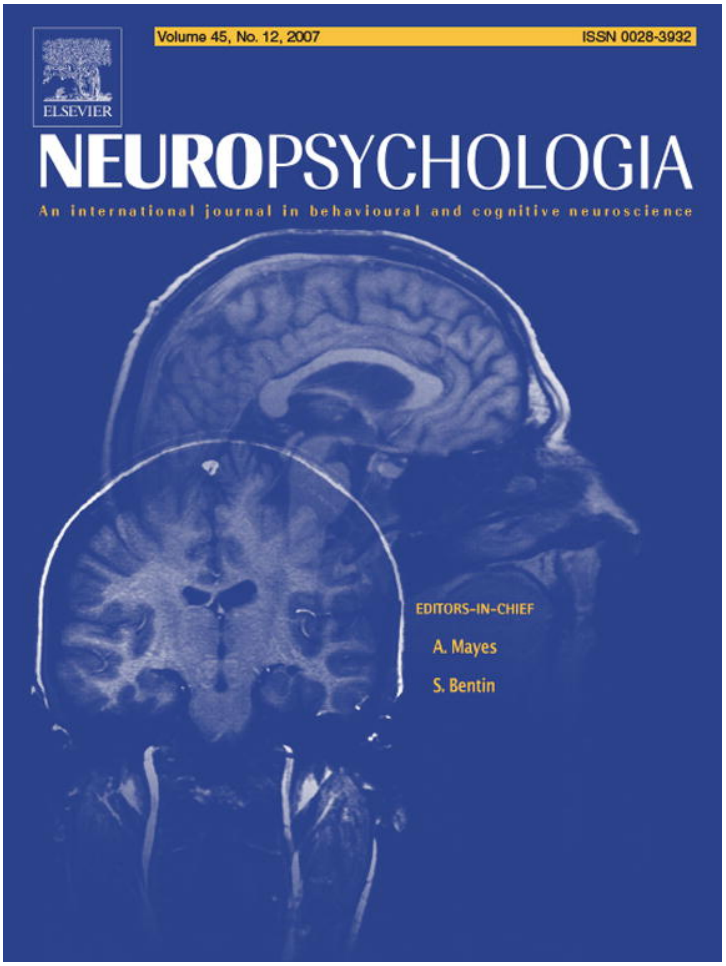

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Are we sensitive to valence differences in emotionally negative stimuli? Electrophysiological evidence from an ERP study

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Abstract

The present study investigated whether the human brain is sensitive to valence differences in emotionally negative stimuli by recording event-related potentials (ERPs) for extremely negative (EN), moderately negative (MN), and neutral pictures while subjects perform a standard/deviant categorization task, irrespective of the emotional valence of the deviants. Using the same design, we also investigated the sensitivity of the human brain to valence differences in emotionally positive stimuli. Experiment 1 showed that EN stimuli elicited more negative deflections than MN stimuli in the early P2 and N2, later P3, and slow negative wave (SNW) components. In contrast, there were no differences in amplitude or latency in these components during the extremely positive (EP) and moderately positive (MP) conditions of Experiment 2. This suggests that humans are only sensitive to valence differences in negative stimuli, and that these negative valences could be processed differentially throughout the information processing stream even when individuals are highly engaged in a non-emotional task.
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Keywords: Event-related potential; Emotionally negative stimuli; Valence differences; Negativity bias; Sensitivity

1. Introduction

Considerable research indicates that the human brain is especially sensitive to emotionally negative events, and that these events are preferentially processed relative to neutral and positive events (Cacioppo & Gardner, 1999; Delplanque, Lavoie, Hot, Silvert, & Sequeira, 2004; Delplanque, Silvert, Hot, & Sequeira, 2005; Huang & Luo, 2006). Behavioral studies (Hansen & Hansen, 1988; Pratto & Johu, 1990; Wentura, Rothermund, & Bak, 2000) have shown that negative events recruit attentional resources more rapidly, or automatically, relative to positive events. A body of event-related potential (ERP) studies (Carreti'e, Iglesias, Garcia, & Ballesteros, 1996; Carreti'e, Mercado, Tapia, & Hinojosa, 2001; Delplanque et al., 2004, 2005; Huang & Luo, 2006) suggests that the bias for emotionally negative events occurs at each step of the information processing stream, from early visual processing and attention allocation to later higher cognitive processing and reaction readiness. A recent experiment, in which subjects categorized the valence of stimuli, showed that negative stimuli elicited larger P1 amplitudes than positive stimuli as early as 110 ms after stimulus onset (Smith, Cacioppo, Larsen, & Chartrand, 2003). In addition, studies adopting emotionally implicit tasks have shown that the posterior P160 and the anterior P200 components, which are considered as indexes of attention-related process, were both larger for negative stimuli than for positive stimuli (Carreti'e et al., 2001; Delplanque et al., 2004). Besides, it has been consistently demonstrated that this emotional negativity bias also occurs in later cognitive evaluation and context updating processes (Delplanque et al., 2004, 2005; Huang & Luo, 2006; Ito, Larsen, Smith, & Cacioppo, 1998) and this bias has also been observed for response-lateralized readiness potentials (LRP) (Huang & Luo, 2006), which indicates that negative events require less time for reaction readiness relative to neutral and positive events.

As described above, negative events are preferentially processed throughout the information processing stream. It is likely

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that such events are processed differently because it is evolutionarily beneficial to respond to negative events quickly (Huang & Luo, 2006). However, the valence of the negative event is important, as extremely negative events typically represent a greater threat to survival than do moderately negative events. As a result, variations in valence have differential effects, with moderately negative events having a lesser effect on cognitive processes (e.g. memory) than do extremely negative events. In fact, extremely negative events can severely affect memory and lead to unwise decision making; furthermore, excessive parasympathetic activity caused by high levels of fear can even lead to sudden death (Coon, 2000; Huang & Luo, 2004a; Watkins et al., 1996). Thus, it is likely that negative events of varying valences are processed differentially with regards to their effect on survival, despite the fact that they share the same valence polarity (negative). In contrast, valence differences in positive events are often unattended to in daily life, as positive events typically bring no harm. Although anecdotal evidence suggests that humans are sensitive to valence differences in negative events, and insensitive to those in positive events, this issue has yet to be directly investigated and there is no neurophysiological evidence to account for this phenomenon.

As is common in natural situations, emotional activity often occurs unpredictably and is triggered by some accidental stimulations (most commonly in social interaction situations, some accidental words from other people offend us in a conversation). Thus, an experimental design that does not require subjects to evaluate valence may allow emotional responses in the laboratory setting to more closely resemble nature. Previous ERP studies have shown that the information processing stream is modulated to a greater extent by negative stimuli than by positive stimuli, even when subjects did not specifically assess emotional valence (Carreti'e et al., 2001; Delplanque et al., 2004, 2005; Huang & Luo, 2006; Smith et al., 2003). Similarly, since negative events of varying valences are distinct in their significance to survival and they have differential effects on cognitive processes, it is also possible that some of information processing stages would be modulated differentially by negative stimuli of varying valences even when subjects are engaged in a non-emotional task. More specifically, based on the above analyses, if high temporal resolution ERP technique be employed, it is likely for us to see that ERPs elicited by negative stimuli of extreme valences differ from ERPs elicited by those of moderate valences in several stages during the information processing stream though subjects focus on a non-emotional task. By contrast, as emotionally positive events, whether they are extremely or moderately positive, have reduced adaptive values compared with emotionally negative events, positive stimuli of differential valences may induce smaller, or even no ERP differences from one another relative to negative stimuli under the same experimental circumstance. Thus, employing ERP technique, the purpose of the present study was to investigate whether humans process negative stimuli of varying valences differentially throughout information processing stream in a task that does not involve valence evaluation, and in which the occurrence of emotional stimuli is unpredictable and accidental. For a comparison, under the same experimental circumstance we also investigated the sensitivity of humans to valence differences among positive stimuli.

The present study used a modified oddball paradigm that required subjects to make a standard/deviant distinction by pressing different keys, irrespective of the emotional valence of the deviants. Rather than requiring a single response for the deviants, we designed two responses to mask the true purpose of the experiment, so as to avoid a "relevance-for-task" effect that was repeatedly reported to obscure the effect of valence on ERPs (Carreti'e et al., 1996, 2001). As a cultural bias for the International Affective Picture System (IAPS) has been reported in Chinese subjects (Huang & Luo, 2004b), the pictures used to elicit emotional responses in current study were from the native Chinese Affective Picture System (CAPS) (Bai et al., 2005). In addition, as previous studies have shown that arousal can non-specifically mask the influence of valence on ERPs (Carretie', Iglesias, & Garcia, 1997; Johnson, 1993), in present study the arousal level of the three valence conditions was low and was matched between any two valence conditions, in particular, between the neutral pictures and the two valence-differed picture groups.

2. Materials and methods

2.1. Subjects

As paid volunteers, 12 adults (7 women, 5 men) aged 21–26 years (mean age, 23.2 years) participated in the study. All subjects were healthy, right-handed, with normal or corrected to normal vision, and reported no history of affective disorder. Each subject signed an informed consent form for the experiment. The experimental procedure was in accordance with the ethical principles of the 1964 Declaration of Helsinki (World Medical Organization, 1996).

2.2. Stimuli

The present study included two modified oddball paradigm experiments. Each experiment consisted of 6 blocks of 100 trials, with each block including 70 standard and 30 deviant (grouped into 3 conditions) pictures. All deviants pictures were taken from the CAPS.[1] In Experiment 1, a natural scene of cup served as the frequent standard picture and 30 pictures grouped as either extremely negative (EN), moderately negative (MN), or neutral served as the deviants. In Experiment 2, a natural scene of a bench served as the frequent standard picture, and 30 pictures grouped as either extremely positive (EP), moderately positive (MP), or neutral served as the deviants. The sequence of standard and deviant pictures was randomized in both experiments for each subject. In Experiment 1, the three groups of deviant pictures differed significantly in valence from one another [mean: EN = 1.85, MN = 3.52, neutral = 5.46; $F(2, 87) = 266.19$, $P < 0.001$; Max (EN) = 2.20, Min (MN) = 2.98] but were similar in arousal (mean: EN = 6.08, MN = 5.88, neutral = 5.86; $F(2, 87) = 1.49$, $P = 0.23$). Similarly, the deviant pictures presented in Experiment 2 were significantly different in valence [mean: EP = 7.41, MP = 6.60, neutral = 5.41; $F(2, 87) = 96.16$,

[1] The standardized CAPS was developed in key laboratory of mental health, Chinese academy of sciences in order to avoid the cultural bias of emotional inducement found in Chinese participants when IAPS was used. For the CAPS development 46 Chinese university students (23 males and 23 females) were collected to rate the valence, arousal, and dominance by self-report in a nine-point rating scale for 852 pictures. The results showed that the system is reliable across participants in emotional inducement (the between-subject reliability scores were 0.982 for valence and 0.979 for arousal). The CAPS introduced a number of scenes of oriental characteristics and oriental faces. More details about CAPS are accessible in Bai et al. (2005).

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$P < 0.001$; Max (MP) = 6.96, Min (EP) = 7.00] but were similar in arousal (mean: EP = 5.58, MP = 5.40, neutral = 5.37; $F(2, 87) = 1.29$, $P = 0.28$). All pictures were identical in size and resolution (15 cm × 10 cm, 100 pixels per inch). In addition, the luminance level of the pictures was matched between any pair of the three valence conditions during either experiment, and the contrast of the monitor was set to a constant value across experiments and subjects.

2.3. Behavioral procedures

Subjects were seated in a quiet room at approximately 150 cm from a computer screen with the horizontal and vertical visual angles below 6°. Prior to the experiment, all subjects were told that the purpose of the study was to investigate their ability to make a fast response selection, and their ability to inhibit the prepotent response to the frequent picture when the deviant appears. At the end of each of the six blocks, accuracy rates for both standard and deviant stimuli were given to the subjects as a feedback of their performance. Each trial was initiated by a 300 ms presentation of a small black cross on the white computer screen; then, a blank screen whose duration varied randomly between 500 and 1500 ms was followed by the onset of picture stimulus .Each subject was instructed to press the "F" key on the keyboard (as accurately and quickly as possible) if the standard picture appeared, and to press the "J" key if the deviant picture appeared. The stimulus picture was terminated by a key pressing, or was terminated when it elapsed for 1000 ms. Therefore, each subject was informed that their responses must be made under 1000 ms. Each response was followed by 1000 ms of a blank screen. Pre-training with 10 practice trials was used before each experiment in order to familiarize subjects with the procedure, and the standard picture in each pre-training was the same as that in the subsequent formal experiment whereas the deviants for pre-training were neutral pictures that were not selected for the formal experiment. All subjects achieved 100% accuracy on 10 practice trials prior to the formal experiment. Each subject participated in both experiments, with the order of the two experiments counterbalanced between subjects.

2.4. ERP recording and analysis

Electroencephalography (EEG) was recorded from 64 scalp sites using tin electrodes mounted in an elastic cap (Brain Products), with the references on the left and right mastoids and a ground electrode on the medial frontal aspect. Vertical electrooculograms (EOGs) were recorded supra- and infra-orbitally at the left eye. Horizontal EOG was recorded as the left versus right orbital rim. EEG and EOG activity was amplified with a dc ∼ 100 Hz bandpass and continuously sampled at 500 Hz/channel. All electrode impedances were maintained below 5 kΩ. ERP averages were computed off-line; trials with EOG artifacts (mean EOG voltage exceeding ±80 μV), amplifier clipping artifacts, or peak-to-peak deflection exceeding ±80 μV were excluded from averaging.

EEG activity for correct response in each valence condition was overlapped and averaged separately. ERP waveforms were time-locked to the onset of stimuli and the average epoch was 1200 ms, including a 200 ms pre-stimulus baseline. As shown by the ERP's grand averaged waveforms and topographical map, the ERPs elicited by EN and MN conditions showed prominent differences from each other in Experiment 1 and these differences were largest at central and frontal sites (see Figs. 1 and 2). In contrast, the grand average ERPs of Experiment 2 displayed no obvious differences during three valence conditions (see Fig. 3). Thus, we selected the following 16 electrode sites for statistical analysis: Fz, FC3, FC4, FCz, FPz, FC1, FC2, C1, C2, Cz, C3, C4 (12 central and frontal sites); CP1, CP2, CPz, and Pz (4 central-parietal and parietal sites). For both experiments, the amplitudes (baseline to peak) and peak latencies (from stimulus onset to the peak of each component) of the P2 (140–200 ms), N2 (230–290 ms), and P3 (350–450 ms) components were measured and analyzed. The amplitudes and the peak latencies were determined with an automated peak-finding software entitled Vision Analyzer. In Experiment 1, the average amplitude of slow negative waves (SNWs) at 450–650 ms was also measured. A two-way repeated measures analysis of variance (ANOVA) was conducted for the amplitude and latency of each component. ANOVA factors were valence condition (three levels: EN, MN, and neutral for Experiment 1; EP, MP, and neutral for Experiment 2)

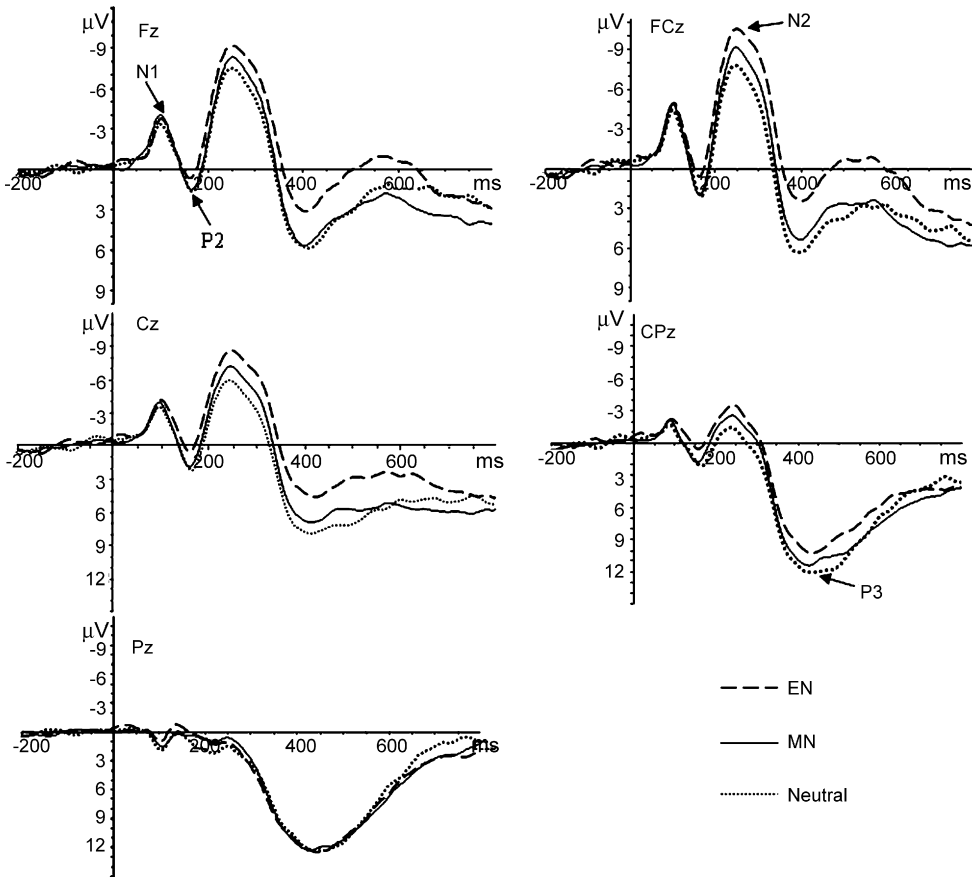

Fig. 1. Top and left-bottom: average ERPs at Fz, FCz, Cz, CPz and Pz for EN (dashed line), MN (solid line), and neutral (dotted line) conditions in Experiment 1.

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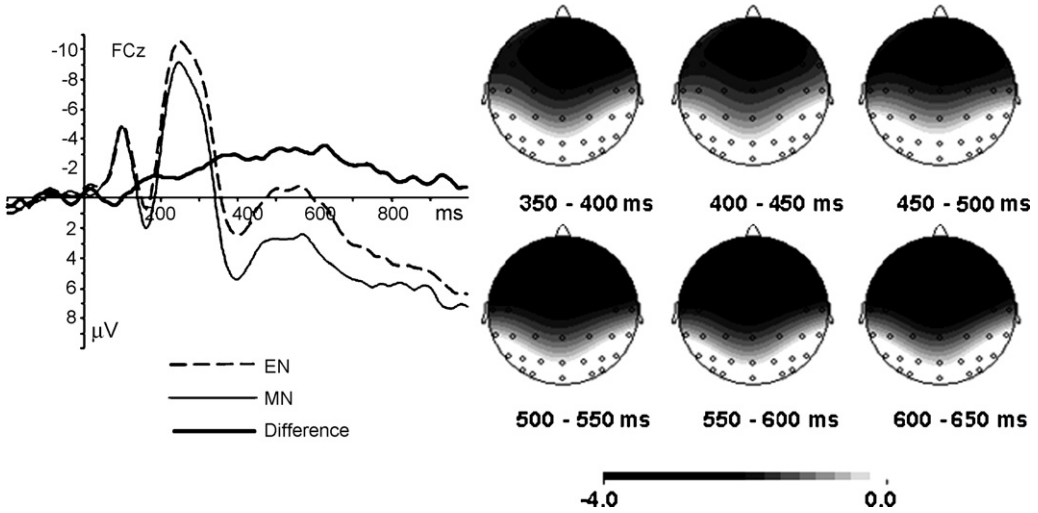

Fig. 2. Left: the average ERPs for EN (dashed line) and MN (solid line) conditions and the EN minus MN difference wave (bold line) at FCz. Right: topographical maps of voltage amplitudes for the EN − MN difference wave at each 50 ms interval from 350 to 650 ms.

and electrode site (16 sites). The degrees of freedom of the *F*-ratio was corrected according to the Greenhouse-Geisser method.

3. Results

3.1. Behavioral performance

The mean reaction times (RTs) for the EN, MN, and neutral conditions in Experiment 1 were 523.9, 524.6, and 517.9 ms, respectively. A one-way ANOVA showed there was no main effect of valence [$F(2, 33) = 0.09$, $P > 0.1$]. In Experiment 2, mean RTs for the EP, MP, and neutral conditions were 518.3, 539.5, and 545.02 ms, respectively. Similar to Experiment 1, there was no main effect of valence [$F(2, 33) = 1.21$, $P > 0.1$]. In addition, the average RTs for the three valence conditions did not differ significantly across the two experiments [$t(70) = 1.00$, $P > 0.1$]. False responses were rare, as nearly all subjects achieved 100% accuracy for both the standard and deviant pictures. Thus, behavioral responses to the deviant pictures were not affected by differences in valence in either experiment, which indicates that the experimental design did preoccupy subjects in standard/deviant categorization task, thus effectively masked the true objective of the study.

3.2. ERP analysis

As shown in Fig. 1, N1, P2, N2, and P3 components were elicited by all three valence conditions in Experiment 1. In this experiment, a significant main effect of valence was found for

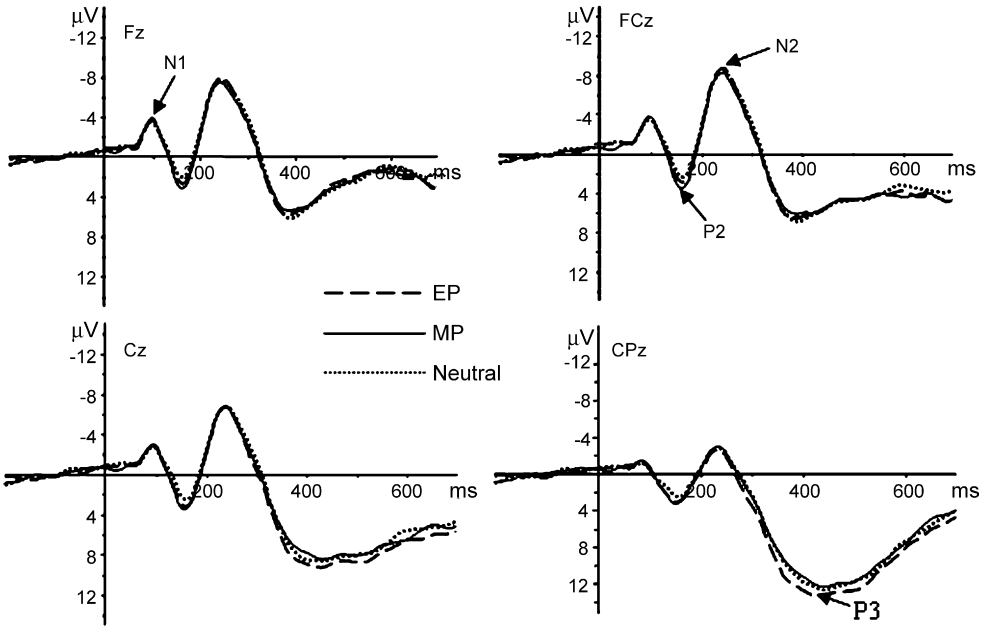

Fig. 3. Average ERPs at Fz, FCz, Cz and CPz for EP (dashed lines), MP (solid lines), and neutral (dotted lines) conditions in Experiment 2.

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Table 1
The mean latencies of P2, P3 components collapsed across the 16 selected electrode sites in EN, MN and neutral conditions in Experiment 1 (*M*: mean; S.D.: standard deviation)

Valence	P2		P3	
	M	S.D.	*M*	S.D.
EN	162.96	18.46	401.96	24.45
MN	169.10	19.75	410.84	27.53
Neutral	171.41	18.23	412.31	24.57

P2 [$F(2, 22) = 7.44, P < 0.01$], N2 [$F(2, 22) = 8.15, P < 0.01$], and P3 [$F(2, 22) = 9.50, P < 0.01$] amplitudes. Additionally, a main effect of amplitude at electrode sites was significant for both N2 [$F(15, 165) = 55.75, P < 0.01$] and P3 [$F(15, 165) = 9.43, P < 0.01$] components. Largest N2 amplitudes were recorded at frontal-central electrode sites [e.g. FCz, FC1, FC2] and all anterior sites displayed larger N2 than posterior sites; whereas central-parietal and parietal sites displayed larger P3 amplitudes than did the anterior sites. Moreover, significant latency effect for valence was observed in P2 [$F(2, 22) = 5.053, P < 0.05$], with P2 latency shorter in EN than in MN and neutral conditions (Table 1). Latency effect for valence was also observed in P3 component [$F(2, 22) = 4.51, P < 0.05$], and the latency was shorter in EN condition than in MN and neutral conditions (Table 1). No other significant main effects or interactions were observed.

A subsequent pairwise comparison for valence and amplitude showed that the EN condition elicited smaller P2 amplitudes than did the MN [$F(1, 11) = 5.15, P < 0.05$] and neutral [$F(1, 11) = 13.6, P < 0.01$] conditions; there were no differences between the MN and neutral conditions. The EN condition also elicited larger N2 amplitudes than MN [$F(1, 11) = 8.36, P < 0.05$], which, in turn, elicited larger N2 amplitudes than the neutral condition [$F(1, 11) = 5.83, P < 0.05$]. Lastly, the EN condition elicited smaller P3 amplitudes than did the MN condition [$F(1, 11) = 4.97, P < 0.05$] and the neutral condition [$F(1, 11) = 11.00, P < 0.01$]. The difference between the MN and neutral conditions was marginal [$F(1, 11) = 3.48, P < 0.09$].

As shown in Fig. 1, after P3 peaked EN stimuli elicited a more negative deflection than did the MN and neutral conditions during the 450–650 ms interval, particularly at anterior recording sites. In contrast, ERPs elicited by MN and neutral stimuli overlapped following the peak of P3. A two-way repeated measures ANOVA on the average amplitude during the 450–650 ms interval showed that both valence, and the interaction between valence and electrode sites, were significant [$F(2, 22) = 6.38, P < 0.01$; $F(30, 330) = 5.22, P < 0.05$]. The simple effects analyses for the valence by electrode interaction showed that the amplitude differences between EN and the other two valence conditions were confined to anterior sites (e.g. Fz, C2, Cz, FC3, FCz, etc.)

ERP averages in Experiment 2 are displayed in Fig. 3. A two-way repeated measure ANOVA showed there was no significant effect of valence on amplitude for the P2 [$F(2, 22) = 0.46, P = 0.579$], N2 [$F(2, 22) = 0.93, P = 0.41$] or P3 [$F(2, 22) = 0.44, P = 0.628$] components, nor was there a latency effect at these components. Thus, neither amplitude nor latency difference was observed between any paired three valence conditions in P2, N2,and P3 components in this experiment. However, both N2 and P3 amplitudes showed significant main effects for electrode site [$F(15, 165) = 27.48, P < 0.001$; $F(15, 165) = 29.37, P < 0.001$]. Whereas larger N2 amplitudes were elicited at anterior electrode sites, P3 amplitudes were larger at posterior sites. No other significant main effects or interactions were found in Experiment 2.

4. Discussion

In Experiment 1, we found that early visual processing (reflected by N1) was similarly affected by all three valence conditions, most likely because the stimuli were pictures of natural scenes, equal in size and resolution. At approximately 170 ms after stimulus onset, obvious frontal P2 activity was elicited in all three conditions, and smaller P2 amplitudes were observed for the EN condition than for the MN and neutral conditions over a wide region across the scalp. Frontal P2 activation within 200 ms is indicative of rapid detection of typical stimulus features (Thorpe, Fize, & Marlot, 1996) and even the early positivity within 150 ms after stimulus onset could be modulated by threatening information in implicit emotional task (Li, Li, & Luo, 2005; Pourtois, Grandjean, Sander, & Vuilleumier, 2004). Thus, our finding of smaller P2 amplitudes in the EN condition is likely indicative of a rapid feature detection process that attends to threatening content (Li et al., 2005). Relative to MN and neutral pictures, EN pictures often included salient threatening content (e.g. bleeding), which has been shown to recruit human attention resources rapidly and automatically (Hansen & Hansen, 1988; Li et al., 2005). Accordingly, in the present study the detection of salient threatening features was facilitated. Consistent with this interpretation, we also observed shorter P2 latencies for the EN condition than for the MN and neutral conditions, which suggests that humans can detect extremely negative features much faster than moderately negative or neutral features. As 170 ms is a very early time point, the facilitated detection of negative features and the early attentional bias towards salient threats probably occurs subconsciously at this stage, and perhaps only a few of features were detected by the nervous system (Huang & Luo, 2006). In contrast, the emotional content of the MN condition (e.g. scenes of protest, aggression) was not detected at early time points, as indexed by the overlapping of P2 activity for MN and neutral conditions. The attentional bias of the human brain to extremely negative features is of great significance to survival as it allows humans to quickly detect danger and make an appropriate response.

Consistent with previous evidence that N2 is sensitive to the presentation of negative facial expressions in the oddball paradigm and may signal the change of attention towards biologically significant events (Campanella et al., 2002; Halgren & Marinkovic, 1995), in the present study N2 amplitudes were largest during the EN condition and smallest during the neutral condition. In addition, the N2 component displayed a central and frontal distribution, which is in agreement with the findings of Nagy, Potts, and Loveland (2003). Previous studies have

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shown that the anterior N2 component represents the allocation of attention to novel, potentially salient stimuli, and that N2 activity elicited by deviant visual stimuli is indicative of voluntary attention in a rare target detection task (Campanella et al., 2002; Nagy et al., 2003). In the present study, it appears that information processing reached a voluntary attention level at the N2 component, which peaked at approximately 260 ms. In contrast to P2, the N2 component was significantly larger in the MN condition than in the neutral condition; this indicates that the emotional negativity of MN stimuli was detected, and that MN stimuli obtained more attentional resources than neutral stimuli. This is most likely because, at the conscious level, as more stimulus features are detected the brain begins to integrate the features into meanings, thus leading to the detection of emotional content in the MN condition. On the other hand, EN stimuli elicited the largest N2 amplitudes of the three conditions (i.e. EN stimuli elicited significant larger amplitude than MN stimuli), indicating that EN stimuli elicited the most attention resources due to their important adaptive value. Therefore, in this stage the brain not only perceives the emotional negativity of MN stimuli but also the valence differences between EN and MN stimuli, and thus differentially allocates attention to these stimuli.

P3 (or LPC) signals the cognitive evaluation of stimuli's meaning (Huang & Luo, 2006; Ito et al., 1998). In the present study, P3 elicited by EN stimuli had shorter latencies than those elicited by the MN and neutral conditions, which indicates that the meaning of EN stimuli are preferentially analyzed and evaluated. Moreover, EN stimuli evoked the smallest P3 amplitudes, and neutral stimuli evoked the largest. This is consistent with several lines of evidence that negative stimuli elicited smaller P3b amplitudes than neutral stimuli over a wide range of recording sites in implicit emotional task (Carreti'e et al., 1996; Delplanque et al., 2004). It has been widely demonstrated that posterior P3 is an index of an inhibition of task-irrelevant information, and also represents later conscious categorization, decision-making and premotor response-related activities (Campanella et al., 2002, 2004; Donchin, 1981; Goldstein, Spencer, & Donchin, 2002). As such, the size of P3 amplitudes in the present experiment may reflect the degree to which individuals inhibit the task-irrelevant but information-laden emotional negativity of the negative deviants. For a subject to make a correct behavioral response to the stimulus (standard versus deviants), all task-irrelevant information had to be inhibited. Therefore, the emotional negativity of the EN condition (with the greatest information burden) should have required the strongest inhibition, which would account for the small P3 amplitudes. The MN condition probably elicited larger amplitudes than the EN condition because the emotional negativity of MN stimuli required less inhibition than EN stimuli. In fact, during a post-experiment interview session all subjects reported that they detected some salient threatening scenes; however, they were more concerned with the accuracy and speed of their responses, and thus the details of the pictures were ignored. These self-reports are consistent with an inhibition process interpretation.

Interestingly, P3 amplitudes were only marginally different between the MN and neutral conditions. In contrast, N2 amplitudes during the MN condition were significantly different from those elicited during the neutral condition. This indicates that MN and neutral stimuli are processed differently during the attentional processing stage. However, in later stages there was only a trend towards a difference between MN and neutral conditions. Considering that the P3 component reflects a deliberate controlled process in which the significance of emotional information is evaluated, and that stimuli with differential emotional values can be differentiated in this stage (Huang & Luo, 2006; Ito et al., 1998), we hypothesize that an evaluation process contributed to the marginal difference seen between MN and neutral stimuli. This controlled evaluative process allowed the brain to recognize that the emotional negativity of MN stimuli is not as salient or threatening as that of EN stimuli, and thus no inhibition processes were needed.

However, the present finding that negative stimuli elicited smaller P3 amplitude than neutral stimuli is incongruent with the converging evidence from overt emotional studies that negative stimuli elicited larger P3 amplitude than neutral stimuli (Huang & Luo, 2006; Ito et al., 1998; Schupp, Junghöfer, Weike, & Hamm, 2003). In overt emotional studies, subjects are usually required to evaluate the emotionality of the stimuli and categorize them according to valence (Huang & Luo, 2006; Ito et al., 1998; Schupp et al., 2003). As negativity bias in emotional processing has been well established, and higher order cognitive processes such as evaluation of stimulus meaning and categorization processing are embodied in LPC (or P3) component (Donchin, 1981; Ito et al., 1998). It could be expected that emotionally negative stimuli would be evaluated as more evolutionarily important and recruit more physiological and psychological resources relative to other stimuli, which contributed to the higher P3 amplitude under negative condition in overt emotional task. However, in implicit emotional experiments, as the task is unrelated to affective evaluation, and emotionally negative information draws attentional resources rather automatically (Hansen & Hansen, 1988; Smith et al., 2003; Wentura et al., 2000), subjects had to overcome the emotional negativity bias that favors the processing of negatively valenced information so that they can successfully complete the experimental task. Thus, inhibitive process is needed, which most probably contributes to the smaller P3 amplitude under negative condition. Therefore, the present study suggests that the choice of experimental methods (covert versus overt) most possibly accounts for the amplitude relation of P3 during negative and neutral conditions.

During the 450–650 ms interval, the SNW elicited by EN stimuli was more negative than those elicited by the other two conditions (Fig. 1) and no significant difference was found between the MN and neutral conditions. The emotional processing indexed by LPC involves a reference to emotional experiences stored in long term memory, and a broad distribution of SNW across the scalp is representative of later memory-related processes (Goode, Goddard, & Pascual-Leone, 2002; Huang & Luo, 2006). As such, it is likely that EN stimuli evoked a rich association with emotional negativity from long term memory, and thus contributed to the increased negativity of SNW during the EN condition. In contrast, it can be inferred

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that fewer emotional associations and emotional memories were evoked by MN stimuli, as similar waveforms were found for both the MN and neutral conditions after the peak of P3. Taken together, the differential processing of EN and MN stimuli not only occurs in the early feature detection and voluntary attention allocation stages, but also takes place in later cognitive evaluation and memory-related processes.

Contrary to the findings of Experiment 1, there were no differences in amplitude or latency in the P2, N2, or P3 components for the two positively valenced conditions in Experiment 2. This indicates that humans are insensitive to valence differences in emotionally positive stimuli throughout the information processing stream. This lack of an effect is probably due to the reduced adaptive value of positive stimuli. Regardless of whether they are extreme or moderate, positive events are not threatening to individual survival, and therefore, physiological and psychological resources are not diverted to detect the differences in valence. Besides, two positively valenced conditions both showed no differences from the neutral condition throughout the information processing stream, which corresponds to the previous finding that discriminating positive and neutral stimuli was more difficult relative to discriminating negative and neutral stimuli (Huang & Luo, 2006). Thus, being highly engaged in non-emotional task, subjects did not process positive stimuli distinctly from neutral stimuli in current experiment, which contrasts with the remarkable negativity bias (compared with neutral stimuli) observed in present Experiment 1 and other non-emotional tasks (Carreti'e et al., 1996, 2001; Delplanque et al., 2004; Li et al., 2005). This similar processing during two positive and neutral conditions also evidences the reduced adaptive value of emotionally positive stimuli, which is the most likely reason for the similar ERP effects observed during the two positive conditions of varying valences in the present experiment.

5. Conclusion

The present study showed that valence does not need to be categorized by subjects for the human brain to process valence differences in negative stimuli throughout the information processing stream. These findings contribute to our understanding of the emotional negativity bias: besides the special sensitivity of human brain towards emotionally negative events over positive and neutral ones, humans are also sensitive to valence differences in negative events. Furthermore, the present findings suggest that the human brain is insensitive to valence differences in positive events.

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Appendix A. Identification numbers of CAPS pictures presented in this study

EN: 173, 185, 191, 194, 196, 205, 206, 232, 240, 243, 244, 246, 248, 254, 255, 256, 270, 273, 280, 284, 471, 533, 541, 569, 573, 577, 580, 629, 583, 584.

MN: 585, 212, 617, 618, 150, 220, 247, 251, 252, 264, 265, 267, 272, 285, 507, 547, 553, 557, 565, 563, 228, 249, 154, 155, 157, 161, 169, 171, 621, 592.

Neutral (negative): 89, 294, 306, 388, 454, 482, 538, 521, 523, 547, 614, 619, 696, 716, 722, 850, 308, 309, 321, 326, 328, 357, 377, 402, 634, 645, 719, 810, 363, 300.

MP: 1, 2, 5, 6, 8, 9, 21, 23, 24, 25, 33, 34, 36, 38, 41, 44, 46, 49, 50, 53, 56, 59, 60, 66, 79, 82, 83, 85, 87, 99.

EP: 4, 7, 10, 11, 12, 13, 14, 16, 18, 20, 28, 29, 45, 40, 52, 72, 73, 77, 78, 88, 94, 84, 39, 57, 32, 98, 27, 65, 663, 819.

Neutral (positive): 840, 841, 843, 547, 89,306, 454, 482, 538, 521, 523, 614, 722, 848, 308, 321, 326, 328, 377, 402, 634, 645, 810, 363, 300, 291, 816, 818, 838, 839.

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