The Effect of Task Relevance on Electrophysiological Response to Emotional Stimuli*

Baolin Liu[1], Shuai Xin[1], Zhixing Jin[1], Xiaorong Gao[2], Shangkai Gao[2], Renxin Chu[3], Yongfeng Huang[4], and Beixing Deng[4]

[1] Department of Computer Science and Technology, Tsinghua University, Beijing 100084, P.R. China
[2] Department of Biomedical Engineering, Tsinghua University, Beijing 100084, P.R.China
[3] Brigham and Women's Hospital, Harvard Medical School, Boston, MA 02115, USA
[4] Department of Electronic Engineering, Tsinghua University, Beijing 100084, P.R. China
liubaolin@tsinghua.edu.cn

Abstract. To verify whether or not the emotion processing is modulated by task relevance, in this paper two tasks are performed - Simple Task and Complex Task. In the Simple Task, negative pictures are target stimuli, while in the Complex Task white-framed negative pictures are target stimuli. Subjects are required to respond when a target stimulus is onset. The EEG (electroencephalogram) epochs are averaged and ERP (event-related potential) components are obtained. The P300 amplitude is smaller in the Complex Task than in the Simple Task, which proves that the emotion P300 is significantly modulated by task relevance. As P1 and N1 amplitudes are decreased in the Complex Task comparing with the Simple Task, we can suggest that the P1/N1 components elicited by emotional stimuli are modulated by task relevance, too.

Keywords: Emotion, ERP, P300, Attention, Task relevance.

1 Introduction

ERPs aroused by emotional stimulus had already been deeply studied before and were illustrated with quite a number of examples, such as the studies on the integration of emotion and working memory [1,2,3,4], the integration of emotion and inhibitory control [5,6,7], and Attentional Blink effect to emotional stimuli [8,9]. Researchers showed a strong interest in P300 components which were influenced by emotional valence. P300 waves aroused by negative pictures were finally proved to be stronger through the previous studies [10,11,12,13,14,15].

However, P300 is not the earliest ERP component related to emotion perception. There was a family of task-relevant ERP components prior to the P300 [16,17,18]. For example, an enlarged P1 component could be observed over posterior scalp sites

* This work is supported by the National Basic Research Program of China (973 program) (No. 2006CB303100 and No.2007CB310806) and by the National High Technology Development Program of China (No.2007AA010306 and No.2006AA01Z444), and by the National Natural Science Foundation of China (No.30630022).

F. Sun et al. (Eds.): ISNN 2008, Part I, LNCS 5263, pp. 97–106, 2008.

contralateral to the attended visual field than unattended [19]; Heinze and Mangun [20] studied the ERP waves elicited by bilateral and unilateral stimulus, and got the result that the early P1 component reflected the facilitation of visual inputs at attended locations on visual processing. Commonly, N1 component was also regarded as an indicator of emotion effect (more positive ERPs for pleasant and unpleasant stimuli than for neutral stimuli). In those studies in which stimuli were presented rapidly and unpredictably to the right and left visual fields, paying attention to the events in one field produced an amplitude enhancement of the early Pl, N1 and/or N2 components elicited by those stimuli over the contralateral occipital scalp [21,22,23,24].

Many ERP researches on the emotional modulation of attention and/or task performance had already been done. For instance, emotional modulation of attention shifting was investigated in Posner's [25] spatial orienting task by conditioning the attention cued to an aversive white noise; Phelps *et al.* [26] provided the evidence for emotion potentiating the effects of attention on low-level visual processing in stimulus-driven attention. Furthermore, we could see the stronger ERP components actually reflected the increasing attentional resources devoted to the processing of emotional stimuli [27,28,29,30]. There were also some studies on emotional modulation of task. For example, it was already exemplified that negative emotions had been demonstrated to improve task performance [31].

There were already some researches on emotion perception modulated by task relevance or attention. Gierych *et al.* [32] designed two experiments to investigate the ERP responses to "smile-provoking" pictures. In the first experiment, both affective stimuli were set as targets in an "oddball" procedure, being presented among the more frequent green disks. Then in the second experiment, they were both non-targets whereas the green disks were task-relevant. Both experiments and all pairs of stimuli produced similar results, which indicated that affective stimuli might produce attentional reallocation of processing resources.

However, ERP researches on task-modulated emotion were limited, and most of the current studies were based on fMRI (functional magnetic resonance imaging) or PET (positron emission tomography) method.

Harlan *et al.* [33] did some experiments with task-related fMRI to investigate how attentional focus could modulate the ERPs elicited by scenes that varied in emotional content. They manifested that the response to emotional task-relevant scenes was strengthened. Meanwhile, in another research by fMRI, Lane *et al.* [34] showed that a higher-arousing effect was aroused when participants attended to their own emotional responses than when participants were attending to the spatial setting of the stimulus (indoor/outdoor/either). These results suggested a higher-arousing effect when subjects attended to the emotional aspect of a stimulus to a greater extent. Based on these experiments, we could tell that if the attention was distracted by added factors, the arousal effect would decrease due to the attention deficit.

In the perceptual grouping study by Han *et al.* [35], the stimulus arrays were either evenly distributed, grouped into rows or columns by proximity or similarity, around by colored dots, or with a fixation cross. As a result, the elicited Pd100 was significantly modulated by the task relevance; in the research of Attentional Blink (AB) effect to emotional stimuli (120 pictures of the IAPS- International Affective Picture System) [9], participants were required to name the black-framed target stimuli aloud. Similarly with the stimuli that they used, we designed a Complex Task, in which the subjects were required to identify the white-framed negative stimuli, and a Simple Task, in which the subjects were only required to response when a negative picture was onset. We would like to verify whether or not the emotion processing is modulated by task relevance.

2 Materials and Methods

Twenty-seven subjects (13 females and 14 males), mean age 22.3 (±3.4) years, were recruited from undergraduate students of Tsinghua University. All the subjects participated in the two experiments. The participants were screened by phone and written questionnaire for history of neurological and psychiatric illness, drug abuse, and psychotropic medication use. They were all right-handed and had normal or corrected-to-normal vision. Handedness was measured using the Edinburgh Handedness Inventory (EHI) [36]. All participants filled in the Volunteer Screening Form and were paid (RMB20/ hour) for their participation.

All experiments were conducted in accordance with the Declaration of Helsinki and all the procedures were carried out with adequate understanding of the subjects, who read and signed the Research Consent Form before participating in this research.

All the subjects were required to complete the positive affect- negative affect scales (PANAS) questionnaire [37]. The PANAS was a 30 item questionnaire producing 6 scores of positive affects (PA) and negative affects (NA) altogether and had been correlated with both hemispheric asymmetry in brain processes of emotional perception and sensitivity to affective manipulation [38]. A one-way ANOVA (analysis of variance) analysis showed there was no significant difference between the subjects in their PANAS scores.

84 pictures were selected from the IAPS [39,40] according to the valence dimension (28 pleasant, 28 unpleasant, and 28 neutral). The pictures were divided into 2 groups, each group has 14 negative pictures, 14 positive, and 14 neutral. They were all presented in a pseudo random sequence.

24 pictures (8 pleasant, 8 unpleasant, and 8 neutral) for the Complex Task were selected and white-framed. Other 18 pictures were not framed. White-framed pictures were more than others to avoid oddball paradigm, which might elicit oddball P300.

The stimuli were conducted on PC (Intel Pentium D, 3.0 GHz, 1 GB RAM) with a 22-inch color monitor. The screen was at a distance of 100 cm from the subjects, and the resolution was 1440 × 900 pixels. The luminance of the pictures was determined according to the research by Palomba *et al.* [41].

Judging an EEG epoch to be negative or positive was not only by the emotional valence of picture estimated before the experiment, but also the response of each subject. Therefore, if one stimulus, such as a spider, was usually thought negative to most people, but not so to one subject, then we excluded all the data concerning this stimulus after all the experiments.

In the Simple Task, subjects were invited to the laboratory and were required to fill in the Research Consent Form. Then they completed the EHI and PANAS. We used a one-way ANOVA analysis to exclude the left-handed subjects and the affect-deviant subjects.

Subjects sat in front of the computer screen and received instructions explaining the experimental task. Stimuli were presented on a black background of a 22-inch color monitor at a viewing distance of 100 cm. The room was sound-attenuated and dimly lit. EEG signals were recorded from 19 scalp sites (Fp1/Fp2, F3/F4, C3/C4, P3/P4, O1/O2, F7/F8, T3/T4, T5/T6, Cz, Fz and Pz) according to the International 10/20 System [42], using Neuroscan Synamps[2] EEG/ERP system. The reference channel was linked to earlobes. When all the electrodes were attached, we checked each of them and made sure the impedance was < 5 kΩ.

When a subject was ready, the vocal introduction of the task was played to inform that 42 pictures would be presented and there would be a break every 14 pictures. He/she was required to pay full attention to each picture, and press "B" when an unpleasant picture was shown. He/she was instructed to wait until the input screen appeared and then responded as accurately as possible. The entire task lasted about 7 minutes; each picture stimulus was presented for 2s and waited for the response, then the response result screen was shown to tell the subject what he/she has pressed; a 6s interval occurred between two trials, during which the screen was black except for a cross at the center of the screen, on which the subject were instructed to fixate. The trials were in a pseudo random order.

All subjects used both hands to make responses. The "B" button was selected as the response key to negative stimuli. He/she could select another button on the keyboard for both the positive and the neutral stimuli. We selected "B", which was the first letter of "Bad" and was just above the space button which was disabled to avoid misoperation. The self-selection button could counterbalance the hand differences between the subjects.

There were two candidate words in the result screen: "bad" (when "B" was pressed) or "not bad" (when another key was pressed), which was presented at the central position. After that, the white cross was shown for 6s until the next picture appeared. No cross was shown while the pictures were presenting.

The Complex Task was modified as follows based on the Simple Task: 42 pictures were used in this task -14 pleasant (numbered 1-14), 14 unpleasant (numbered 15-28) and 14 neutral (numbered 29-42). Subjects could not see the internal numberings of each picture. The following pictures were selected and white-framed: 1-8; 15-22; 29-36; a subject was required to press "B" if it is both negative and white-framed. He/she would press the self-selected key in other cases.

The EEG from each electrode site was digitalized at 256 Hz with an amplifier band pass of 0.01-40 Hz, including a 50 Hz notch filter and was stored for off-line averaging.

Subjects were required to give an integer score between 1 and 9 to each of the pictures as a self-assessment to their emotional reactions after all the experiments, where score 1 indicated very unpleasant picture, 9 indicated very pleasant picture, 5 indicated neutral stimuli.

A one-way ANOVA analysis on these scores showed there was no significant difference between the mean arousal ratings of the pictures in two tasks.

3 Results

Computerized artifact rejection was performed to discard epochs in which deviation in eye position, blinks, or amplifier blocking occurred [43]. The rejected epochs were considered invalid. We selected the datasets of the best 20 subjects (7 females and 13 males), and all datasets of the other 7 subjects were rejected. At last, about 20% of the selected 20 subjects' trials (the negative epochs) were rejected for violating these artifact criteria.

The EEG epochs we selected were 100 ms prior the stimulus onset and 900ms after stimulus onset.

Fig. 1 shows the average ERPs to unpleasant, pleasant, and neutral stimuli in the Simple Task. We can see the amplitude differences (P300 amplitude in response to unpleasant pictures is significantly higher than that in response to either pleasant pictures or neutral pictures) clearly from it.

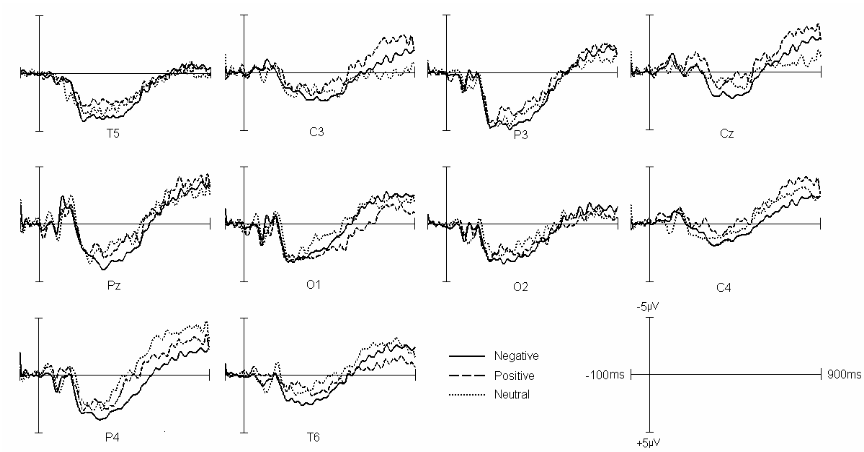

Fig. 1. The average ERPs to unpleasant, pleasant and neutral stimuli in the Simple Task. P300 amplitude in response to unpleasant pictures is significantly higher than that in response to either pleasant pictures or neutral pictures.

Studies using neuroimaging techniques and source modeling analyses had shown that effects of emotional stimuli are strongest in occipital and posterior brain locations [44,45,46], so we paid most of our attention to occipital and posterior electrode sites: parietal electrodes (P3, P4 and Pz), occipital electrodes (O1 and O2), and temporal-occipital electrodes (T5 and T6).

Additionally, what we practically cared about was the modulation itself rather than the emotional valence here. Therefore, we averaged the negative EEG epochs, which elicited more robust emotion effects, to obtain the emotional ERPs.

We plotted the negative ERPs (ERP waves evoked by negative pictures, at sites T5, T6, P3, P4, O1, O2 and Pz) of both the Simple Task and the Complex Task in Fig. 2. By comparison, we could see the decrease of P300 amplitude in the Complex Task at all sites, as well as the shorter P300 latency of Complex Task at most of the sites clearly.

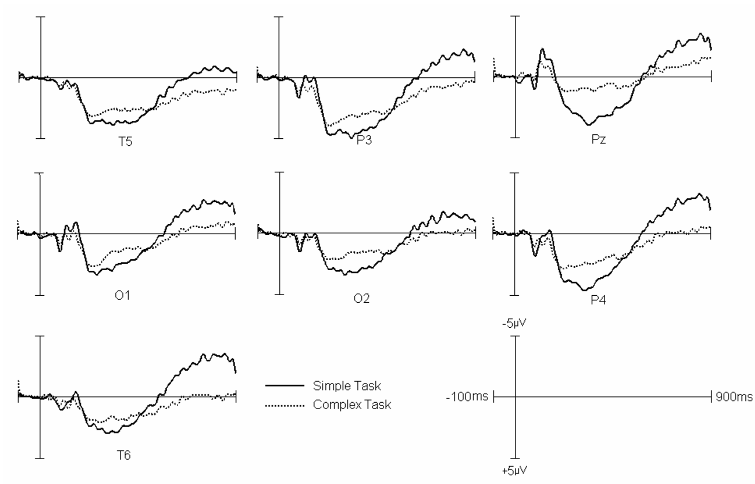

Fig. 2. Averaged ERP waveforms evoked by negative pictures: Simple Task vs. Complex Task. We can see the P300 latencies are significantly shorter in the Complex Task than in the Simple Task at parietal electrode sites (P3, P4 and Pz) and temporal-occipital electrode sites (T5 and T6), and the P300 amplitudes are significantly larger in the Simple Task than in the Complex Task at all concerned sites.

The negative P300 amplitude was significantly larger in the Simple Task than in the Complex Task at all concerned sites (P3 [$F(1,38)=82.84$, $p<0.001$], P4 [$F(1, 38)=104.62$, $p<0.001$], Pz [$F(1,38)=316.31$, $p<0.001$], O1 [$F(1,38)=14.64$, $p<0.001$], O2 [$F(1,38)=53.30$, $p<0.001$], T5 [$F(1,38)=28.53$, $p<0.001$] and T6 [$F(1,38)=40.07$, $p<0.001$]) (see Fig. 2).

The P1 amplitude was significantly decreased in the Complex Task than in the Simple Task at all concerned sites O1 [$F(1,38)=46.51$, $p<0.001$], O2 [$F(1,38)=9.29$, $p<0.005$], P3 [$F(1,38)=15.40$, $p<0.001$], P4 [$F(1,38)=62.59$, $p<0.001$], Pz [$F(1,38)=54.44$, $p<0.001$], T5 [$F(1,38)=7.94$, $p<0.01$] and T6 [$F(1,38)=5.13$, $p<0.05$] (see Fig. 2).

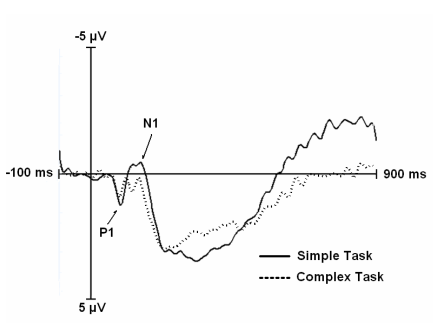

Fig. 3. Grand average negative ERPs for sites T5, T6, P3, P4, Pz, O1 and O2 of the Simple Task and the Complex Task

The N1 amplitude was significantly decreased in the Complex Task than in the Simple Task at all concerned sites O1 [$F(1,38)=44.36$, $p<0.001$], O2 [$F(1,38)=19.18$, $p<0.001$], P3 [$F(1,38)=38.14$, $p<0.001$], P4 [$F(1,38)=42.22$, $p<0.001$], Pz [$F(1,38)=67.17$, $p<0.001$], T5 [$F(1,38)=16.65$, $p<0.001$] and T6 [$F(1,38)=33.90$, $p<0.001$] (see Fig. 2).

For further comparison, we plotted the grand average negative ERPs (ERP waveforms evoked by negative pictures) of sites T5, T6, P3, P4, Pz, O1 and O2 in the following figure (Fig. 3). Fig. 3 shows the decreased P300 amplitudes and the shorter P300 latencies clearly in the Complex Task. The decrease of P1/N1 amplitudes could be obviously observed in the Complex Task, too.

4 Discussion

P300 amplitude in response to unpleasant pictures was significantly higher than that in response to either pleasant pictures or neutral pictures, which was consistent with the known studies [10,11,12,13,14,15].

The negative P300 amplitude was significantly decreased at sites T5, T6, P3, P4, Pz, O1 and O2 in the Complex Task comparing with the Simple Task, which showed that the emotion processing was modulated by task relevance.

It was often assumed that P300 amplitude depended on the capacity of processing task relevant stimuli. Meanwhile, Kok [47] suggested that in many tasks, an increase in difficulty influenced the very processes that underlay P300 generation. Thus, we could conclude that in the Complex Task, the task difficulty were enhanced, which resulted in the decrease of P300 amplitude.

The arousal level governed the amount of attention that was available for task performance, and P300 amplitude was hypothesized to index attentional resources. The non-task events might engage attentional resources to reduce P300 amplitude, namely, P300 amplitude was relatively large under simple task conditions [48]. Accordingly, in the Complex Task, P300 amplitude was supposed to be smaller because attentional resources were detracted for task performance.

In fMRI studies, Lane *et al.* [34] suggested there was a higher arousing effect when subjects attended to the emotional aspect of a stimulus to a greater extent. Thus, in the Simple Task, subjects might pay more attention to the emotional stimulus, while in the Complex Task, due to the distraction of the additional factor- white frames, subjects might pay less attention to the emotional aspect of the stimuli.

Amplitude modulation of the P1 and N1 components reflected the selection of the attended spatial location [49,50]. Stimuli at attended locations elicited larger P1/N1 components than those at unattended locations [51]. Hence, as outlined above, we could see that, because of the additional white frame, the selection of the attended spatial location was more uncertain, and the emotional aspect of the stimuli might become unattended, which resulted in the decrease of P1 (at all concerned sites O1, O2, P3, P4, Pz, T5 and T6) and N1 (at all concerned sites O1, O2, P3, P4, Pz, T5 and T6) in the Complex Task.

The N1 component was generally enhanced/reduced along with the P1 to attended stimuli (vs. unattended stimuli) [52,33]. We could see the same result supporting this theory while comparing the Complex Task with the Simple Task.

To sum up, negative pictures produced a significantly larger P300 than either positive or neutral pictures, which is consistent with the known studies. The P300 amplitude was smaller at all concerned sites T5, T6, P3, P4, Pz, O1 and O2 in the Complex Task than in the Simple Task, which suggested that the emotion P300 was significantly modulated by task relevance. As P1 (at sites T5, T6, P3, P4, Pz, O1 and O2) and N1 (at sites T5, T6, P3, P4, Pz, O1 and O2) amplitudes were decreased in the Complex Task comparing with the Simple Task, we could also suggest that the P1/N1 components elicited by emotional stimuli were also modulated by task relevance.

Acknowledgments. The authors would like to thank NIMH Center for the Study of Emotion and Attention (University of Florida, Gainesville) for providing the pictures of IAPS (The International Affective Picture System).

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