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Automatic processing of valence differences in emotionally negative stimuli: Evidence from an ERP study

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ABSTRACT

The present study investigated the influence of attention on the human sensitivity to valence differences in emotionally negative stimuli. Event-related potentials were recorded for unattended highly negative (EN), moderately negative (MN) and neutral pictures in Experiment 1 which engaged subjects in an auditory discrimination task; and for EN, MN and neutral pictures in Experiment 2 that required visual classification of pictures. Results of both experiments displayed increased negative deflections during EN than during MN and neutral conditions at 150–250, 250–350, and 350–450 ms intervals post-stimulus. Moreover, MN stimuli elicited larger negativity than did neutral stimuli during 250–350 ms interval in either experiment. This developed our understanding of the human sensitivity to valence differences in negative stimuli, by revealing that the brain sensitivity to the valence strength of negative stimuli exists stably, unaffected by attention access to some extent.

Considerable research has shown that emotional processing can occur automatically, in shortage of attention [10,13,15]. Previous studies using neuroimaging measures verified that amygdala responses to threat-related expressions are unaffected by attention [17]. A growing body of event-related potential (ERP) studies observed greater brain responses to unpleasant than to neutral stimuli before 300 ms post-stimulus [4,20], where information processing occurs below conscious threshold [6]. Consistent with these observations, through manipulating attentional load, a recent ERP study showed that negative stimuli presented at unattended locations elicited larger amplitudes of N1-P2 than did unattended neural and positive stimuli [7,8]. Additionally, a recent work by Zhao and Li observed that unattended facial expression of sadness elicited enhanced negativity than did the unattended neutral faces from 120 to 430 ms, suggesting that negative stimuli are processed preferentially, to some extent, independent of attention access [21].

Therefore, emotionally negative stimuli are preferentially processed even in shortage of attention, probably because negative events are biologically important [3]. However, emotionally salient events in life settings are often varying in valence intensity. The valence strength of negative stimuli is important, as intense negative events represent greater threat to survival than do mild negative events. As a result, mild negative emotions have lesser impact on cognitive processes (e.g. memory) than do intense negative emotions [19,20]. In fact, using a covert emotional task that required subjects to make a standard/deviant distinction, irrespective of the emotional valences, previous studies in our lab reported a valence intensity effect that the human brain is sensitive to valence differences in negative, but not in positive, stimuli [19,20]. Consistent with these findings, using facial expressions as materials, studies that employed overt [14] or covert [16] emotional tasks jointly showed increased neural responses of the brain to negative facial expressions of higher intensity.

However, whether covert emotional tasks were used [16,20] or affective assessment was required [14], all these studies required subjects to direct attention to emotional stimuli. With full attention, observation of the brain sensitivity to valence differences in negative stimuli, to some extent, is not surprising due to the biological significance of negative events [19,20]. It is unknown, then, whether the brain remains sensitive to the valence strength of negative stimuli if attentional resources for emotional processing are lacking. Therefore, it is necessary to investigate whether attention availability influences brain susceptibility to valence differences in negative stimuli, as no prior behavioral or electrophysiological studies have directly investigated this issue as yet.

Therefore, using ERP measures, the present study investigated whether the human brain is susceptible to valence differences in negative stimuli in lack of attention to these stimuli. Because negative events of intense salience are more biologically important than mild negative events, and automatic processing of salient events in lack of attention is evolutionarily beneficial [21], we hypothesized that ERPs elicited by intense negative stimuli would differ

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from those elicited by mild negative stimuli even if attention is engaged by a distracting task. Specifically, it is possible to observe that the human brain is differently susceptible to emotionally negative images of diverse valences, irrespective of whether attention is focused on, or distracted from, emotional stimuli. To test these hypotheses, the present study used a "crossmodal delayed response" task [18,21], to realize the shortage of attention to pictures in Experiment 1. Moreover, a visual classification task was used in Experiment 2, to realize subjects' focused attention on pictures.

In Experiment 1, a picture was presented in the interstimulus interval between a tone and a response imperative signal. The task of subjects was to discriminate the pitch of tones, but only to press the button when the response imperative signal appeared. The response imperative signal was designed to be very weak. Therefore, subjects had to focus attention on the detection of the faint response imperative signal, consequently to realize the shortage of attention to pictures. In Experiment 2, a red cross was presented 300–500 ms after the offset of picture stimuli, and subjects were required to discriminate whether the picture was standard or deviant, but responded by buttonpress only when the red cross appeared. Therefore, subjects had to focus on pictures, consequently to realize the active attention to pictures. Because emotional pictures were deviant stimuli in both experiments, and attention involvement in deviant stimuli is essential to the generation of P3 activity [9], we predict that emotional pictures in Experiment 2 would elicit clear P3 activity which, however, is absent in Experiment 1 due to lack of attention to pictures. In addition, as previous studies have shown that arousal can nonspecifically mask the influence of valence on ERPs [5], in present study the arousal level of the three valence conditions was matched between any two valence conditions.

Twelve undergraduates (six female, six male), 19–22 years of age, were paid to serve as subjects in the study. All of them were right-handed with normal hearing and vision or corrected visual acuity. They reported no history of affective disorder. Each subject signed an informed consent form for the experiment.

The present study included two experiments. Each experiment consisted of 5 blocks of 120 trials, with each block including 84 standard and 36 deviant (grouped into three conditions) pictures. Thus, the onset ratio of standard vs. deviant pictures was 7:3 in both experiments. In Experiment 1, each trial was composed of a sequence of three stimulus events, namely, one of two equiprobable auditory targets (800 and 1000 Hz tones), a visual picture and an auditory click (response imperative signal). The tones' duration was 30 ms (including 5 ms rise/fall time) and the intensity was 60 dB SPL. Each tone (800 or 1000 Hz) was followed by the 200 ms presentation of a picture that was then followed by a faint auditory click (2 ms, 18 dB SPL). Similarly, each trial of Experiment 2 (visual task) comprised a sequence of three events: a black cross, one standard or deviant picture, and a red cross. The picture was presented for 200 ms and the red cross for 1000 ms. In both experiments, all pictures were taken from Chinese Affective Picture System [1] (CAPS).[2] A natural scene of a 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. The sequence of standard and deviant pictures was randomized for each subject. The EN, MN and neutral 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], while their arousal values were matched across valence conditions (mean: EN = 6.08, MN = 5.88, neutral = 5.86; $F(2, 87) = 1.49$, $P = 0.23$). All pictures were identical in size and resolution (15 cm × 10 cm, 100 pixels per inch).

Subjects were seated in a quiet room at approximately 120 cm from a computer screen with the horizontal and vertical visual angles below 5°. Thirty practice trials were used before either experiment in order to familiarize subjects with the task. Each subject achieved more than 90% accuracy rates in practice trials. For each subject, the performance of Experiment 1 constantly preceded that of Experiment 2, in case that the priori attentional focus on images in Experiment 2 may decrease the threshold to consciously detect emotional stimulus onset in Experiment 1.

In Experiment 1, auditory stimuli were delivered to earplug through air tubes in order to mitigate electromagnetic stimulus artifacts. Subjects were told to fixate on the central point of the screen, and to attend to auditory signals rather than visual pictures. Immediately a tone was presented, subjects were required to discriminate the pitch of the tone and prepared for a response with either their left or right thumb, depending on whether the tone was 800 or 1000 Hz. Instead of an immediate response, their responses should be made after the presentation of a weak click (i.e. the response imperative signal), whose occurrence is unpredictable. Once the response imperative signal (click) appeared, they were asked to press the button as quickly and accurately as possible. The interstimulus interval from tone to picture was set pseudorandomly between 250 and 450 ms, while that between picture and the click varied between 300 and 500 ms. The inter-trials interval ranged randomly between 800 and 1000 ms.

In Experiment 2, subjects were told to fixate on the central point of the screen. 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 1000 ms was followed by the presentation of a picture stimulus for 200 ms. The picture was then replaced by a 300–500 ms blank screen which, in turn, was followed by the presentation of a red cross. Each subject was instructed to press the "F" key on the keyboard when the red cross followed the standard picture, and not to press any key when the cross followed deviant pictures. Therefore, deviant pictures had the same duration, were free of motor responses across the two experiments. The small red cross was terminated by a key pressing, or when it elapsed for 1000 ms. Each response was followed by 1000 ms of a blank screen.

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 10 kΩ. ERP averages were computed offline; trials with EOG artifacts (mean EOG voltage exceeding 80 μV), amplifier clipping artifacts or peak-to-peak defection exceeding ±80 μV was excluded from averaging. EEG activity for correct responses in each valence condition was averaged separately.

[2] 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 [11]. The CAPS introduced a number of pictures characterized by oriental natural scenes and oriental faces. The development method of this native emotional picture system is similar to that of IAPS. For the CAPS development, originators first collected over 2000 pictures of various contents for the system development, and finally kept 852 pictures most of which are typical of Chinese cultures for the normative ratings. Chinese college students (gender-matched) were recruited to rate the valence, arousal, and dominance by a self-report 9-point rating scale for the 852 pictures of the system. The pretest for this system showed that CAPS is reliable across individuals in emotional inducement (the between-subjects reliability scores were 0.982 for valence and 0.979 for arousal).