Published in final edited form as:

Neurosci Lett. 2012 September 27; 526(2): 118–121. doi:10.1016/j.neulet.2012.08.011.

Fearful faces evoke a larger C1 than happy faces in executive attention task: an event-related potential study

Xiang-ru Zhu and

Department of psychology, Henan University, Beijing, China, +86-15993358320,
zhuxiangru@gmail.com

Yue-jia Luo

State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University, Beijing, China, +86-5880-2365, luoyj@bnu.edu.cn

Abstract

Neural responses to negatively valenced stimuli such as fear are enhanced relative to positive or neutral stimuli, reflecting an emotional negativity bias. In the present study, high time resolution event related potential (ERP) techniques were used, to investigate whether C1, the earliest visually evoked potential, is modulated by emotional valence in the executive attention network. Subjects were instructed to respond to the expression of the face, while ignoring the content of word, in an emotional face-word Stroop task. We demonstrated modulation of C1 in response to fearful faces versus happy faces. The differentiation between detection of fearful and happy faces emerged at 60–90 ms after the stimulus onset at the posterior electrode sites, and this early differentiation occurred regardless of whether the subject had viewed a congruent or incongruent trials (i.e. happy face with fear label or vice versa). The present results indicate that faces with a fearful expression capture processing resources at an early sensory processing stage.

Keywords

fear; happy; executive attention; C1

Introduction

Emotional expressions provide universal signals of one's emotional state and communicate reactions to biologically salient events in the environment. Signals of potential danger, which are associated with the need to avoid harm, take particularly high precedence [1]. Substantial evidence suggests neural responses to negatively valenced stimuli such as fear, are enhanced relative to responses to positive or neutral stimuli, reflecting an emotional negativity bias [2,3,4], and there is some evidence that the earliest visually evoked potential component, termed the C1 [5], is sensitive to the emotional valence. The main aim of the present study was to investigate whether the fearful face evoked a larger C1 than the happy face in an executive attention task.

© 2012 Elsevier Ireland Ltd. All rights reserved.

Corresponding author: Yue-jia Luo, luoyj@bnu.edu.cn, telephone number: 5880-2365, facsimile number: 5880-2365.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

A great number of studies have showed that emotional negativity bias could occur in several temporal stages [6]. A large proportion of research findings found, at the early stage, several ERP components (e. g., P1, N1, about 100 ms after the stimuli onset) elicited by negative stimuli have been found to be more pronounced than those elicited by positive and neutral stimuli. This stage mainly distinguishes potentially threatening facial expression from the other expressions. The emotional negativity bias may be attributed to processing in this stage. However, several previous studies have shown emotional valence can modulate a component in the C1 latency range [5,7], which is earlier than the P1 and N1 time range. Employing high-density electroencephalography (EEG), Pourtois et al. [7] found that fearful faces elicited greater C1 amplitude (peaking 80~100 ms after stimulus presentation) than happy ones. The early event-related potential (ERP) component C1, is thought to represent activation of primary visual cortex (V1), though recently it has been suggested that V2 or V3 may also be the source of C1 [8]. The early C1 valence effect is consistent with the view that fear processing has a fast and automatic subcortical route to the amygdala [9].

Nevertheless, the C1 component was not consistently modulated by emotional valence. Thus, consistent with the literature that valence-related C1 effects have not been consistently observed across previous studies [6], the optimal conditions for eliciting such effects remain uncertain. Whether the C1 modulated by the emotional valence may be related to the attentional process involved in the task. The orienting network may be particularly relevant for C1 sensitivity to emotional valence as a previous study indicated that a fearful face stimulus evoked a larger C1 than a happy face stimulus in the orienting network [7]. According to the attention network theory, attention involves three major, largely independent functional networks: the alerting, orienting and executive control networks [6]. Briefly, the alerting network involves maintenance of the alert state. The orienting network is involved in the selection of and orienting toward sensory information. And the executive control network refers to the process of resolving cognitively incongruent stimuli. It has not yet been clarified whether C1 is larger for fearful versus the happy faces in an executive attention task.

The anterior cingulate cortex (ACC) is the key neural basis of the executive attention network [10]. Recently, studies revealed that brain regions implicated in human executive control are also critically involved in processing negative emotion. For example, affective visual stimuli trigger a greater mobilization of resources than neutral stimuli in attention-related areas in the ACC [11]. Such findings raise questions about how much processes related to executive control and negative emotion processing interact. Indeed, negative emotion has been reported to have the capacity to enhance executive control in a flanker task [12], and individuals with high control capacities show enhanced processing of negative emotion compared with control subjects [13]. Such findings support the notion that processing of negative emotions may be prioritized in executive attention tasks.

The main aim of the present study was to investigate whether a fearful face stimulus evokes a larger C1 than a happy face stimulus in an executive attention task. We employed the emotional face-word Stroop task, a paradigm generally used to examine the executive attention, in which a face image is presented with a word that may be congruent or incongruent with the emotion being expressed by the face [10], together with ERP analysis, which allows for high temporal resolution of neural activity and thus is particularly well suited for investigating the temporal sequence of emotion processing. Given the key role of ACC in the emotion-attention interactions [11], we predicated that ERPs generated in response to fearful and happy faces would differentiate at an early processing stage in the emotional conflict task, and potentially replicate the fear modulation effect in the early C1 time window.

Methods

Participants

Sixteen healthy right-handed subjects (7 male and 9 female) were recruited from Beijing Normal University. The average age was 22.5 years ($SD = 2.1$). They had no history of brain injury. The subjects were paid for their participation. One male subject was excluded for analysis due to excessive artifacts.

Stimuli and Procedure

Happy and fearful facial expression photographs were each consisted of 10 male and 10 female faces selected from Chinese facial affective picture system [14,15]. The Chinese words ‘愉快’ (“yukuai”, means happy) or ‘恐惧’ (“kongju” means fear) written in prominent red color across the faces, such that the valences of word and expression were either congruent or incongruent (Fig. 1). The size of the Chinese characters in bold face was about 1° (horizontal) $\times$ 1° (vertical).

The trial sequence was the same as Egner et al’s study [10]. The present experiment consisted of 24 blocks, each block contained 37 presentations of congruent and incongruent stimuli (the first one was not included). Each trial began with the presentation of a fixation for 1500–1800ms. After the fixation, the stimuli (3.5° wide, 5° high) appeared in the center of the screen. Stimuli were presented for 1000 ms. Subjects were instructed to respond as quickly and accurately as possible, by pressing response buttons corresponding to “happy” (right index finger) or “fear” (right middle finger) for the expression of the face. Subjects were seated in a room facing a monitor placed at 80 cm distance from the eyes.

ERP recording

The electroencephalogram (EEG) was recorded from 64 scalp sites using tin electrodes mounted in an elastic cap (NeuroScan Inc., Herndon, Virginia, USA) according to the International 10/20 System. Horizontal electrooculogram (HEOG) was recorded from electrodes placed at the outer canthi of both eyes to record horizontal eye movement. Vertical electrooculogram (VEOG) was recorded from electrodes placed above and below the left eye to record vertical eye movements. All electrode recordings were referenced to an electrode placed at the right mastoid. And the impedances of them were all maintained below 5 k Ω . The EEG and EOG were amplified using a 0.05–100 Hz bandpass and continuously sampled at 500 Hz/channel.

Data measure and analysis

After data acquisition, the EEG data were re-referenced offline to linked mastoid electrodes by subtracting from each sample of data recorded at each channel one-half the activity recorded at the left mastoid. Ocular artifacts were corrected with an eye-movement correction algorithm suggested by Gratton [16]. The EEG data were low-pass filtered below 30 Hz (12dB/oct). Separate EEG epochs of 1000ms (200 ms baseline) were extracted offline for the stimuli. Error trials were discarded from all analyses. All trials in which EEG voltages exceeded a threshold of $\pm 50\mu V$ during the recording epoch were excluded from analysis. C1 (60–90 ms) was analyzed at the Oz, O1, O2, POZ, PO3 and PO4 electrode sites (peak to baseline). For the C1 amplitude analysis we used the following within subjects factors: face valence (two levels: fearful face and happy face), conflict (two levels: congruent and incongruent) and electrode site (six levels: Oz, O1, O2, POZ, PO3 and PO4). For all analyses, P values were corrected for deviations according to Greenhouse Geisser [17].

Results

Behavioral performance

For the behavioral result, error trials (about 4% of the total) were not analyzed. The overall conflict effect in response time was significant, $t(1, 14) = 7.86, p < 0.001$. Congruent trials were responded to faster than incongruent trials. The conflict effect in error rate was also significant, $t(1, 14) = 5.21, p < 0.001$. Errors were less in congruent trials than in incongruent trials.

ERP data

The ERP results were shown in Fig.2. For the C1 amplitudes, repeated-measures ANOVAs showed that the main effect of valence was significant, $F(1, 14) = 13.88, p = 0.002$, a main effect of electrode, $F(1, 14) = 10.70, p < 0.001$, the interaction between valence and electrodes significant, $F(5, 70) = 6.25, p = 0.001$. The main effect of congruency and other interactions were not significant, $ps > 0.09$.

For the latency, repeated-measures ANOVAs showed that the main effect of electrodes was significant, $F(5, 70) = 6.24, p = 0.003$. The main effect of valence and congruency and other interactions were not significant, $ps > 0.09$.

To investigate the habituation effect, we split the whole blocks as first half (12 blocks) and second half, and made a two factor repeated ANOVA for emotion factor (fear and happy) and block factor (first half and second half). Result indicated the block effect was not significant.

Discussion

The present study revealed that fearful faces evoked a larger C1 than the happy faces, which peaked 60~90 ms after the stimulus onset at posterior sites. This C1 effect was not modulated by the congruency (i.e. concurrent presentation with fitting vs. conflicting words) and there was no effect of block period.

The lack of an effect of congruency on ERP modulation indicated that early differentiation was not modulated by the ACC-related conflict control network. The conflict related studies [18] have shown that, ACC involvement in conflict monitoring or conflict control occurs at least 200 ms after stimulus onset, more than 100 ms after the differentiation between fearful and happy faces observed in our study. We cannot exclude the contribution of the other attentional functions of the ACC in the present results. Dosenbach et al [19] found the ACC related attentional network operates in a long strategic mode rather than in a trial by trial mode. Due to the conflict engendered by the emotional face-word Stroop task, subjects needed to expend mental effort to complete the task. Hence, it is possible that the ACC might have contributed to the C1 effect via a state mode, though not on a trial by trial basis.

Given that each condition contained more than 400 trials, it is important to determine whether stimulus repetition led to an adaptation of emotion processing that could in and of itself result in different rates of habituation for fearful versus happy faces [20]. Adaptation effect of emotion processing is thought to be reflected in the N1 component which occurs more than 100 ms after stimulus presentation [20]. Importantly, the modulation effect observed in the present experience occurred earlier than N1. Moreover, in addition to the fact that our ANOVA showed no effect of block period, we found no interaction between block period and trial emotion (fearful and happy). Cortical facilitation of fear expression processing was apparent early in the first half of the trial block and did not habituate during

the second half. Hence, we can have confidence that the observed condition differences cannot be attributed to fatigue or habituation.

Whether the presently observed early differentiation between fearful and happy faces can be attributed to the previously characterized C1 *per se* remains to be clarified. Recent studies using EEG recordings over the scalp, the C1 component can only be produced when stimuli are presented in the upper or lower visual field [5,7]. However, in the face-word Stroop task, as employed here, the stimuli were presented centrally. As described previously, presentation of faces centrally or along the meridians prevents visualization of early retinotopic effects in C1. However, inspection of the present data on the single-subject level indicated that the fear modulation of the early electrocortical response was highly consistent across individuals. Hence, in the present study, we emphasized the timing of the effect without assuming its source. It is possible that the early modulatory effect manifested as C1 rapidly following stimulus onset may be caused by direct feedback effects exerted from distant deep limbic structures, such as the amygdala, onto the occipital cortex, including V1. Indeed, although C1 was first attributed to V1 [7], other regions—including the V2, V3, the bilateral ventral occipito-temporal regions and the right anterior medial temporal regions have also been implicated in the C1 effect [21]. Thus further studies are needed to elucidate the source of the C1 in emotional task.

One point to consider is that we cannot completely exclude some impact of task-irrelevant word processing during the present task because we used word present with face simultaneously. Due to the technical limitation used in the present study, we cannot isolate task-relevant face processing and task-irrelevant word processing as the previous fMRI study did [22]. Though we cannot exclude the contamination of word processing completely, our observation that the early differentiation between fearful face and happy face was not modulated by the congruency of the trial in the present study, indicated the processing of word is likely has no influence on the processing of the face in so early time window.

In conclusion, the present study, supports the notion that fearful face processing may take priority over happy face processing in the executive attention system, which manifested as an enhanced C1 for the fearful face than the happy face. Future research should explore whether the C1 effect exists in other attention system, such as the alerting system.

References

1. Wang L, Fu S, Feng C, Luo W, Zhu X, Luo YJ. The neural processing of fearful faces without attention and consciousness: an event-related potential study. *Neuroscience Letters*. 2012; 506:317–321. [PubMed: 22155093]
2. Vuilleumier P, Schwartz S. Emotional facial expressions capture attention. *Neurology*. 2001; 56:153–158. [PubMed: 11160948]
3. Vizireanu N, Halunga S, Marghescu G. Morphological skeleton decomposition interframe interpolation method. *Journal of Electronic Imaging*. 2010; 19:1–3.
4. Vizireanu DN, Udrea RM. Visual-oriented morphological foreground content grayscale frames interpolation method. *Journal of Electronic Imaging*. 2009; 18:1–3.
5. Stolarova M, Keil A, Moratti S. Modulation of the C1 visual event-related component by conditioned stimuli: evidence for sensory plasticity in early affective perception. *Cerebral Cortex*. 2006; 16:876–887. [PubMed: 16151178]
6. Luo WB, Feng WF, He WQ, Wang NY, Luo YJ. Three stages of facial expression processing: ERP study with rapid serial visual presentation. *NeuroImage*. 2010; 49:1857–1867. [PubMed: 19770052]
7. Pourtois G, Grandjean D, Sander D, Vuilleumier P. Electrophysiological correlates of rapid spatial orienting towards fearful faces. *Cerebral Cortex*. 2004; 14:619–633. [PubMed: 15054077]

8. Ales JM, Yates JL, Norcia AM. V1 is not uniquely identified by polarity reversals of responses to upper and lower visual field stimuli. *NeuroImage*. 2010; 52:1401–1409. [PubMed: 20488247]
9. Williams MA, Morris AP, McGlone F, Abbot DF, Mattingley JB. Amygdala responses to fearful and happy facial expressions under conditions of binocular suppression. *Journal of Neuroscience*. 2004; 24:2898–2904. [PubMed: 15044528]
10. Egner T, Etkin A, Gale S, Hirsch J. Dissociable neural systems resolve conflict from emotional versus nonemotional distracters. *Cerebral Cortex*. 2008; 18:1475–1484. [PubMed: 17940084]
11. Canli T, Desmond JE, Zhao Z, Glover G, Gabrieli JDE. Hemispheric asymmetry for emotional stimuli detected with fMRI. *Neuroreport*. 1998; 9:3233–3239. [PubMed: 9831457]
12. Kanske P, Kotz SA. Emotion triggers executive attention: anterior cingulate cortex and amygdala responses to emotional words in a conflict task. *Human Brain Mapping*. 2011; 32:198–208. [PubMed: 20715084]
13. Paulus MP, Simmons AN, Fitzpatrick SN, Poterat EG, Van Orden KF, Bauman J, Swain JL. Differential brain activation to angry faces by elite warfighters: neural processing evidence for enhanced threat detection. *PLoS One*. 2010; 5(4):e10096. [PubMed: 20418943]
14. Bai L, Ma H, Huang YX, Luo YJ. The development of native Chinese affective picture system—A pretest in 46 college students. *Chinese Mental Health Journal*. 2005; 19:11.
15. Zhu XR, Zhang HJ, Wu TT, Luo WB, Luo YJ. Emotional conflict occurs at an early stage: evidence from the emotional face-word Stroop task. *Neuroscience Letters*. 2010; 478:1–4. [PubMed: 20417689]
16. Gratton G, Coles MG, Donchin E. A new method for off-line removal of ocular artifact. *Electroencephalography and Clinical Neurophysiology*. 1983; 55:468–484. [PubMed: 6187540]
17. Greenhouse WW, Geisser S. On methods in the analysis of profile data. *Psychometrika*. 1959; 24:95–112.
18. Van Veen V, Carter CS. The timing of action-monitoring processes in the anterior cingulate cortex. *Journal of Cognitive Neuroscience*. 2002; 14:593–602. [PubMed: 12126500]
19. Dosenbach NU, Fair DA, Miezin FM, Cohen AL, Wenger KK, Dosenbach RA, Fox MD, Snyder AZ, Vincent JL, Raichle ME, Schlaggar BL, Petersen SE. Distinct brain networks for adaptive and stable task control in humans. *Proceedings of the National Academy of Sciences of the United States of America*. 2007; 104:11073–11078. [PubMed: 17576922]
20. Carretié L, Hinojosa JA, Mercado F. Cerebral patterns of attentional habituation to emotional visual stimuli. *Psychophysiology*. 2003; 40:381–388. [PubMed: 12946112]
21. Morel S, Beaucoisin V, Perrin M, George N. Very early modulation of brain responses to neutral faces by a single prior association with an emotional context: Evidence from MEG. *Neuroimage*. 2012; 61:1461–1470. [PubMed: 22525875]
22. Morishima Y, Okuda J, Sakai K. Reactive mechanism of cognitive control system. *Cerebral Cortex*. 2010; 20:2675–2683. [PubMed: 20154012]

Highlights

1. The emotional negativity bias was explored in an emotional face-word Stroop task.
2. The differentiation between fear and happy started at about 75 ms.
3. The early differentiation was manifested at the posterior electrode sites.

Fig.1.

Stimuli and example timelines used in the emotional conflict task. Subjects were asked to identify the affect of faces with fearful or happy expressions that had either “fear” or “happy” written across them. Stimuli were either congruent or incongruent with respect to facial expression and word, which created emotional conflict.

Fig.2.

Grand-average waveforms evoked by stimuli at selected electrodes. The region occupied by the gray bar highlights differential aspects of the C1 (60–90 ms) between fearful and happy face trials. Negative amplitudes are plotted upwards.