Neuroscience Letters 526 (2012) 118–121

Contents lists available at SciVerse ScienceDirect

Neuroscience Letters

journal homepage: www.elsevier.com/locate/neulet

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

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HIGHLIGHTS

- The emotional negativity bias was explored in an emotional face-word Stroop task.
- The differentiation between fear and happy started at about 60–90 ms.
- The early differentiation was manifested at the posterior electrode sites.

ARTICLE INFO

Article history:
Received 19 May 2012
Received in revised form 26 July 2012
Accepted 5 August 2012

Keywords:
Fear
Happy
Executive attention
C1

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.

1. 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 [20]. 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 [19,18,17], and there is some evidence that the earliest visually evoked potential component, termed the C1 [15], 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.

A great number of studies have showed that emotional negativity bias could occur in several temporal stages [10]. 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 [15,14], which is earlier than the P1 and N1 time range. Employing high-density electroencephalography (EEG), Pourtois et al. [14] 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 [1]. The early C1 valence effect is consistent with the view that fear processing has a fast and automatic subcortical route to the amygdala [21].

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

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http://dx.doi.org/10.1016/j.neulet.2012.08.011

across previous studies [10], 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 [14]. According to the attention network theory, attention involves three major, largely independent functional networks: the alerting, orienting and executive control networks [10]. 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 [6]. 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 [3]. 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 [9], 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 [6], 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 [3], 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.

2. Methods

2.1. 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.

2.2. 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 [2,22]. 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).

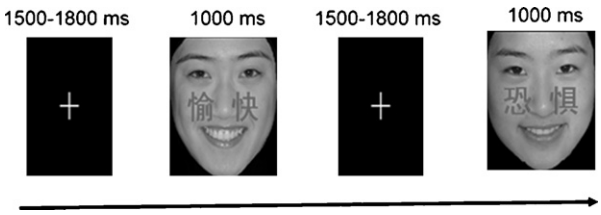

Fig. 1. Stimuli and example timelines used in the emotional conflict task. Subjects were asked to identify the affect of faces with fearful or happy expressions that had either "fear" or "happy" written across them. Stimuli were either congruent or incongruent with respect to facial expression and word, which created emotional conflict.

The size of the Chinese characters in bold face was about 1° (horizontal) × 1° (vertical).

The trial sequence was the same as Egner et al.'s study [6]. 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 1500–1800 ms. 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.

2.3. ERP recording

The electroencephalogram (EEG) was recorded from 64 scalp sites using tin electrodes mounted in an elastic cap (NeuroScan Inc., Herndon, VA, 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 place 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 kΩ. The EEG and EOG were amplified using a 0.05–100 Hz bandpass and continuously sampled at 500 Hz/channel.

2.4. 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 [7]. The EEG data were low-pass filtered below 30 Hz (12 dB/oct). Separate EEG epochs of 1000 ms (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 ±50 μV 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 and Geisser [8].