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Differential early ERPs to fearful versus neutral facial expressions: A response to the salience of the eyes?

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Abstract

Several event-related potential (ERP) studies have demonstrated a negative shift in ERPs for fearful relative to neutral facial expressions ~170–300 ms post-stimulus over occipital-temporal scalp. In the present study, three experiments were conducted to examine the importance of the eye region for this ERP differentiation. ERPs and behavioral discrimination responses were measured to fearful and neutral expressions when only the eye region of the expression was visible (the eyes and eyebrows or the eyes alone) and when the eye region (the eyes and eyebrows or the eyes alone) was covered by dark glasses. The results showed a negative shift in ERPs for fearful relative to neutral expressions over lateral temporal sites, starting ~160–210 ms post-stimulus. The visibility of the eye region but not the eyes per se was critical for these ERP differences to occur. There were, however, indications that information in the eyes is also coded and used in the categorization of facial expressions.

Keywords: Event-related potential; Emotion; Face perception; Facial expression

Specialized neural mechanisms are thought to exist that serve recognition of stimuli relevant to our core motivation of minimizing danger and maximizing pleasure (Williams, 2006). These mechanisms act to ensure that biologically relevant stimuli are rapidly and automatically detected and prioritized in the competition for access to awareness. Consistent with this view, behavioral studies have shown that spatial attention is automatically shifted towards a fearful faces over a simultaneously presented neutral face (Holmes et al., 2005), and that fearful faces hold attention for a longer period of time than neutral faces (Georgiou et al., 2005).

Recordings of event-related potentials (ERPs) have further shown that threat-related (fearful/angry) facial expressions elicit different patterns of brain activity compared to positive/neutral facial expressions starting from components associated with early visual processing (P100, N170). Specifically, the P100 and the face-sensitive N170 components over occipital-temporal scalp regions have been shown to be of larger amplitude for fearful relative to neutral faces (Batty and Taylor, 2003; Leppänen et al., 2007b; Pourtois et al., 2005; Stekelenburg and de Gelder, 2004). Some studies have not confined the analyses to any specific ERP components but have instead quantified ERP differences to threat-related and neutral facial expression over a broader temporal window. These studies have shown a negative shift in ERP activity for fearful/angry relative to neutral expressions, starting at the latency of the N170 component or slightly later and lasting for 100 ms or more (Eimer et al., 2003; Eimer and Kiss, 2007; Leppänen et al., 2007a; Schupp et al., 2004; Sprengelmeyer and Jentzsch, 2006). The negative shift in ERPs to threat-related relative to neutral facial expressions may arise from enhanced processing of emotionally salient stimuli in perceptual representation areas (Schupp et al., 2004). A similar negative shift is observed for task-relevant target stimuli relative to task-irrelevant distractors in studies using non-emotional material such as colors or geometric shapes (Hillyard and Anllo-Vento, 1998). The onset of the negative shift can, therefore, be used as a marker of the time at which emotionally/motivationally relevant and neutral (or task-irrelevant) stimuli have been discriminated and are subjected to differential processing in cortical visual systems.

An important but little investigated question concerns the stimulus features that underlie the rapid discrimination of fearful and neutral facial expressions. One possibility is that fearful facial expressions are detected on the basis of some relatively simple facial features that are "diagnostic" for this category of facial expressions (cf. Smith et al., 2005).

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Facial expressions of fear are characterized by several appearance changes in the face, of which the most important are wide open eyes, furrowed and raised eyebrows, and stretched mouth (Kohler et al., 2004). There are, however, indications that the salience of the eye region in fearful faces may provide the critical diagnostic information that allows fearful facial expressions to be rapidly distinguished from other facial expressions. Most notably, the impairment in the recognition of fearful facial expressions in patients with amygdala lesion appear to be attributable to a failure to utilize information in the eye region (Adolphs et al., 2005). The amygdala, which is thought to play a key role in rapid detection of threat, is activated not only by fearful faces but also by fearful eyes embedded in a neutral face (Morris et al., 2002) and by fearful eyes presented in isolation (Whalen et al., 2004). There is also evidence that early face-related ERPs (N170) are particularly responsive to the eyes (Bentin et al., 1996; but see Eimer, 1998). We are, however, not aware of any studies that would have examined whether the differential processing of fearful and neutral facial expressions in the early stages of cortical processing (i.e., at the level of the N170 component and beyond) is driven by the cues in the eye region.

Fig. 1. Examples of stimuli used in Experiments 1 and 2.

To directly test the hypothesis that the rapid discrimination of fearful and neutral faces is driven by the expressive cues in the eye region, three experiments were conducted to examine ERPs and behavioral reaction times (RTs) to fearful and neutral expressions using face stimuli in which (a) the whole face was visible; (b) only the eye region of the face was visible; and (c) the whole face except the eye region was visible. We hypothesized, first, that if discrimination of fearful and neutral faces is based on the expressive cues in the eye region, then the differential early ERPs to fearful and neutral expressions (i.e., a negative shift in ERPs to fearful expressions ~200–300 ms post-stimulus) should be observed, and fearful and neutral expressions should be behaviorally discriminated at above chance level even when the eye region of the faces is presented in isolation. Second, we hypothesized that covering the eyes impedes the recognition of fearful expressions, resulting in attenuated/abolished early ERP differentiation of fearful and neutral faces, and delayed and less accurate behavioral discrimination of fearful expressions.

1. Experiment 1

In Experiment 1, ERPs to fearful and neutral facial expressions were examined by using a paradigm in which facial expressions were presented as non-target stimuli and observers were not given any specific instructions to explicitly process (i.e., to categorize or label) the expressions. In some studies, ERP differentiation between emotional and neutral faces was observed only when participants were explicitly attending to the emotional content of the facial expressions (e.g., Krolak-Salmon et al., 2001). There are, however, also studies suggesting that reliable effects can also be obtained in a passive task (Batty and Taylor, 2003; Leppänen et al., 2007b).

1.1. Methods

Participants. The participants were 18 volunteers (11 females, age $M = 27$ years, range 18–50 years). Four additional participants were tested but excluded due to excessive artifact and poor signal-to-noise ratio.

Stimuli. The stimuli were color pictures of fearful and neutral facial expressions of two male and two female models from the MacBrain Face Stimulus Set[1] (Tottenham et al., 2002). Fearful and neutral facial expressions with eyes covered were created by drawing "dark glasses" on the original faces (see Fig. 1). This way only the eyes were covered and the stimuli still appeared relatively natural (as opposed, for example, if the eye region had been covered with a black rectangle). The faces subtended approximately $9^\circ \times 12^\circ$ when viewed from a distance of 77 cm. Fearful and neutral expressions with only the eye region of the face depicted were created for each original face. The isolated eyes ("letter box") subtended approximately $7^\circ \times 3^\circ$. Fearful and neutral expressions did not differ in the mean pixel luminance in any of the stimulus conditions ($ps > .25$). Stimulus presentation and timing were controlled by Neuroscan Stim software.

Procedure. Faces with eyes visible, faces with eyes covered, and isolated eyes were presented in three separate blocks, each consisting of a total of 128 face stimuli (64 per emotion category). The ordering of the blocks was balanced between participants. The stimuli were presented for 500 ms followed by a 2000-ms interstimulus interval (ISI). Fearful and neutral expressions were presented in random order. A passive task with no instruction given to the participants to recognize the expressions was used. However, to ensure that the participants attended to the screen throughout the testing session, participants

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