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Research Report

Electrophysiological correlates of the efficient detection of emotional facial expressions

Reiko Sawada[a,*], *Wataru Sato*[a], *Shota Uono*[b], *Takanori Kochiyama*[a], *Motomi Toichi*[b]

[a]*The Hakubi Project, Primate Research Institute, Kyoto University, 41-2 Kanrin, Inuyama, Aichi 484-8506, Japan*
[b]*Faculty of Human Health Science, Graduate School of Medicine, Kyoto University, 53 Shogoin-Kawaharacho, Sakyo-ku, Kyoto 606-8507, Japan*

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ABSTRACT

Behavioral studies have shown that emotional facial expressions are detected more rapidly and accurately than are neutral expressions. However, the neural mechanism underlying this efficient detection has remained unclear. To investigate this mechanism, we measured event-related potentials (ERPs) during a visual search task in which participants detected the normal emotional facial expressions of anger and happiness or their control stimuli, termed "anti-expressions," within crowds of neutral expressions. The anti-expressions, which were created using a morphing technique that produced changes equivalent to those in the normal emotional facial expressions compared with the neutral facial expressions, were most frequently recognized as emotionally neutral. Behaviorally, normal expressions were detected faster and more accurately and were rated as more emotionally arousing than were the anti-expressions. Regarding ERPs, the normal expressions elicited larger early posterior negativity (EPN) at 200–400 ms compared with anti-expressions. Furthermore, larger EPN was related to faster and more accurate detection and higher emotional arousal. These data suggest that the efficient detection of emotional facial expressions is implemented via enhanced activation of the posterior visual cortices at 200–400 ms based on their emotional significance.

1. Introduction

Emotional facial expressions are proposed to have evolved as indispensable communication media for the survival of human ancestors (Darwin, 1872). Rapid and accurate communication via emotional facial expressions would have facilitated immediate sharing of biologically significant information, such as that about predators or food.

Consistent with this idea, several behavioral studies have demonstrated efficient detection of the emotional facial expressions of others using a visual search paradigm. The visual search paradigm has been applied successfully to demonstrate the ability of the human visual system to detect socially important signals in the environment. In previous studies, photographs or drawings of facial expressions were lined up, and participants were asked to respond regarding

*Corresponding author. Fax: +81 568 63 0085.
E-mail address: sawada.reiko.3z@kyoto-u.ac.jp (R. Sawada).

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the existence of different expressions. The results showed that the reaction time (RT) for and accuracy of detecting an emotional face (e.g., angry and happy) in a crowd of neutral faces were shorter and greater, respectively, than were those for a neutral face in a crowd of emotional faces (Hansen and Hansen, 1988; Öhman et al., 2001; Williams et al., 2005). Thus, the detection of emotional facial expressions is more effective than the detection of neutral expressions.

It remains controversial whether the rapid detection of emotional faces could be derived from emotional or visual factors (cf. Cave and Batty, 2006) because emotional and neutral facial expressions are different not only in their emotional significance but also in the change in visual features (e.g., oblique eyebrows in angry expressions versus horizontal eyebrows in neutral expressions). Several behavioral studies have shown that oblique lines were detected more quickly than horizontal lines (Sagi and Julesz, 1986), suggesting that changes in physical features play an important role in the rapid detection of emotional facial expressions. However, a recent behavioral study investigated this issue by manipulating the visual features of photographic facial stimuli (Sato and Yoshikawa, 2010). The researchers presented normal emotional facial expressions (anger and happiness) or control stimuli, termed "anti-expressions" (Sato and Yoshikawa, 2009; for different use of this term, see Skinner and Benton, 2010, 2012), within crowds of neutral expressions. Anti-expressions were created from photographs of emotional facial expressions by using computer-morphing techniques to contain a degree of visual changes equivalent to those in emotional facial expressions compared with neutral facial expressions; however, the anti-expressions were recognized as neutral expressions in free categorical labeling (Sato and Yoshikawa, 2009). This method enabled us to determine whether the rapid detection of emotional facial expressions was attributed to emotional significance or to visual features. Therefore, it was suggested that anti-expressions are promising control stimuli for investigating the effects of emotional significance on the efficient detection of emotional facial expressions (Sato and Yoshikawa, 2009). The previous study showed that the RTs for detecting emotional facial expressions were shorter than those for detecting anti-expressions, indicating that emotional facial expressions are efficiently detected because of their emotional, not their visual, elements (Sato and Yoshikawa, 2010).

Although these accumulating behavioral data have confirmed the rapid and accurate detection of emotional facial expressions, its neural mechanism remains unclear. To measure the brain activity underlying such rapid psychological processing, event-related potentials (ERPs) would be one of the most appropriate tools because of their high temporal resolution. A few recent studies have reported ERP data in visual search tasks with facial stimuli (Feldmann-Wüstefeld et al., 2011; Weymar et al., 2011). However, these studies focused only on differences among emotional categories of targets (i.e., angry versus happy expressions). Thus, no reported study has compared the ERP components for detecting emotional versus emotionally neutral facial targets within neutral distractors. Furthermore, the influence of emotional and visual factors on ERP activity related to the detection of emotional versus emotionally neutral facial targets within neutral distractors has not been examined. There is also no report on the relationships between detection performance or emotional ratings for emotional expressions and ERP activities; such information would be of importance in understanding the functional significance of the influence of emotion on ERP components (Olofsson et al., 2008).

There appear to be two ERP candidates for the electrophysiological correlate of rapid detection of emotional facial expressions. The first is the negative deflection at about 200–400 ms in the bilateral posterior cortices, referred to as early posterior negativity (EPN) (Schupp et al., 2003). Several ERP studies showed that greater EPN was elicited in response to emotional than to neutral facial expressions (e.g., Balconi and Pozzoli, 2003; Sato et al., 2001; Schupp et al., 2004) and in response to emotional than to neutral scenes (e.g., Junghöfer et al., 2001; Schupp et al., 2003; Wiens et al., 2011; for a review, see Olofsson et al., 2008). A previous study also showed that greater EPN was elicited by emotional rather than by neutral scenes, even when some visual factors (e.g., luminance and spatial frequency) were controlled (Wiens et al., 2011). This study also showed that greater EPN was related to higher ratings of emotional arousal for scenery stimuli. Some researchers have suggested that the enhanced EPN for emotional stimuli may reflect heightened perceptual or attentional processing of the stimuli (e.g., Sato et al., 2001; Schupp et al., 2003). These empirical and theoretical data on EPN are consistent with behavioral data indicating the rapid detection of emotional compared with neutral facial expressions, even when controlling for visual factors, and their relevance to emotional arousal (Sato and Yoshikawa, 2010). Thus, we hypothesized that EPN would be the primary candidate for the neural correlate of the efficient detection of emotional facial expressions.

The second candidate is the negative deflection at around 200–400 ms in the posterior cortices contralateral to the target presentation, referred to as N2-posterior-contralateral (N2pc) (Luck and Hillyard, 1994). Several previous ERP studies have shown that greater N2pc was elicited in response to the target stimuli in a visual search paradigm (e.g., Luck and Hillyard, 1994; Woodman and Luck, 1999). Some recent studies tested emotional facial expressions as targets during the detection of emotional targets in a visual search task. These studies showed that greater N2pc was elicited by targets detected more rapidly than by those detected later (Feldmann-Wüstefeld et al., 2011; Weymar et al., 2011). However, these previous studies did not compare emotional with neutral facial expression targets. Regarding the effects of visual versus emotional factors, a study reported that visual factors, such as local features, did not modulate N2pc in response to emotional facial expressions (Weymar et al., 2011). In contrast, another study reported that visual factors were related to N2pc activity in response to emotional facial expressions (Brosch et al., 2011). Moreover, no reported study has investigated the relationship between N2pc amplitude and emotional arousal. Thus, although the evidence is relatively scarce, we predicted that N2pc would be the secondary candidate related to the detection of emotional facial expressions.