ELSEVIER

Neuropsychologia 44 (2006) 2899–2906

NEUROPSYCHOLOGIA

www.elsevier.com/locate/neuropsychologia

Event related potentials and the perception of intensity in facial expressions

Reiner Sprengelmeyer*, Ines Jentzsch

School of Psychology, University of St. Andrews, St. Andrews KY16 9JP, Scotland, United Kingdom

Received 21 January 2006; received in revised form 6 June 2006; accepted 7 June 2006
Available online 7 September 2006

Abstract

It is well known from everyday experience, that facial expressions of emotions can very much vary in intensity, e.g. ranging from mild anger to rage, or from uneasiness and mild fear to angst and panic. However, the effect of different intensities of facial expressions of emotion on event related potentials has yet not been studied. We therefore investigated 16 healthy participants with a gender decision task to male and female faces displaying angry, disgusted and fearful facial expressions varying in intensity (50%, 100%, 150%). Analysis of ERP data showed a significant increase in amplitude of the N170 by intensity, but not by type of emotion. The intensity induced negative variation was most pronounced between 200 and 600 ms at electrodes P9 and P10. For this time segment, there was a clear linear relationship between intensity and degree of negative deflection. A dipole source localisation of the intensity effect using the difference waveform (150% minus 50% intensity) revealed two symmetrically positioned generators within the inferior temporo-occipital lobe. An emotion specific effect for disgust was further found at temporal electrode sites (FT7 and FT8) at around 350–400 ms. Results are summarised in a two-phase model of emotion recognition, suggesting the existence of an initial monitoring process which codes saliency of incoming facial information. In a second step, the specific emotional content of faces is decoded in emotion specific recognition systems.

Keywords: ERP; Facial expression; Basic emotions; Fear; Disgust; Anger; Intensity; N170; Mirror neurons

1. Introduction

The human face is an important source of social signals. It reveals the individual's identity and expresses, if not controlled intentionally, the inner feelings of our counterparts. The importance of facially transmitted signals in guiding interpersonal behaviour is reflected in the complex functional architecture of psychological processes, which is based on a widely distributed neural network, specifically dedicated to decode these information.

One of the most influential models of face processing (Bruce & Young, 1986) suggests an initial structural encoding process, which is followed by separable pathways for processing identity and facial expressions of emotions. Whilst, within this model, identity processing is highly elaborated and fractionated into distinct sub-processes, emotion recognition is represented only as a single and undifferentiated process.

Neuropsychological research in the past decade, however, has added substantially to the understanding of the psychological sub-processes as well as the neural substrates underlying facial emotion recognition.

Deficits in recognising fearful facial expressions after damage to the amygdala have first been described by Adolphs, Tranel, Damasio, and Damasio (1994). These initial findings have since been replicated by numerous neuropsychological studies investigating people with lesions or functional deficits to the amygdala (Broks et al., 1998; Calder et al., 1996; Meletti et al., 2003; Sato et al., 2002; Sprengelmeyer et al., 1999). Functional imaging studies could further show, that recognition of fearful faces is based on a spatially distributed neural network, involving superior colliculi, thalamic relay nuclei, striate and extrastriate regions, as well as the amygdala (e.g. Breiter et al., 1996; Fischer et al., 2003; Morris et al., 1996). Within this network, a fast sub-cortical processing route targeting the amygdala and a slow thalamo-cortical processing route is proposed. The fast processing route forms part of an evolutionary old system which is able to respond rapidly, automatically, and without conscious awareness to signals of threat and danger (LeDoux, 1996).

* Corresponding author.
E-mail address: rhs3@st-andrews.ac.uk (R. Sprengelmeyer).

0028-3932/$ – see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.neuropsychologia.2006.06.020

Evidence for the fast route in humans comes from both single case (De Gelder, Vroomen, Pourtois, & Weiskrantz, 1999) and functional imaging studies (Morris et al., 1998; Morris, De Gelder, Weiskrantz, & Dolan, 2001).

A different pattern of results comes from studies looking at recognition of facial expressions of emotion in people with pre-clinical as well as clinical Huntington's disease (Gray, Young, Barker, Curtis, & Gibson, 1997; Hennenlotter et al., 2004; Sprengelmeyer et al., 1996; Sprengelmeyer, Schroeder, Young & Epplen, 2006; Sprengelmeyer et al., 1997b; Wang, Hoosain, Yang, Meng, & Wang, 2003). Participants with this disorder were particularly impaired in recognising facial expressions of disgust. Other disorders such as Parkinson's disease (Sprengelmeyer et al., 2003), Tourette's syndrome, Obsessive Compulsive disorder (Sprengelmeyer et al., 1997a), and Wilson's disease (Wang et al., 2003) were also associated with deficits in facial disgust recognition. Furthermore, functional imaging studies (Hennenlotter et al., 2004; Phillips et al., 1997; Sprengelmeyer, Rausch, Eysel, & Przuntek, 1998) reported the involvement of the basal ganglia and insula in recognising facial expressions of disgust. But in contrast to fear, there is no evidence for a fast processing route for disgust.

While the association between amygdala and insular-striatal regions and recognition of fear and disgust is supported by numerous studies, there is only one study linking the nucleus accumbens with recognition of facial expressions of anger (Calder, Keane, Lawrence, & Manes, 2004).

However, neuropsychological and functional imaging studies are not able to tell anything about the time course of face processing. To investigate these aspects in detail, various ERP studies have been conducted so far. The most prominent deflection of face related potentials is the N170, first described by Bentin, Allison, Puce, Perez, and McCarthy (1996) and Bötzel, Schulze and Stodieck (1995). Although questioned in the past (Rossion, Curran & Gauthier, 2002; see Bentin & Carmel, 2002 for response), the N170 is now thought to represent the face specific structural encoding process as hypothesised by the Bruce and Young model.

Other studies looked particularly at the ERP modulation associated with processing of facial expressions of emotions. Eimer and Holmes (2002) reported a positive fronto-central ERP component within 200 ms after stimulus onset when comparing neutral with fearful facial expressions. Batty and Taylor (2003) investigated the effect of happy, surprised, fearful, sad, disgusted and angry compared to neutral facial expressions on ERPs and found an overall emotion effect on the N170 and emotion specific modulation of ERPs in the 220–450 ms time window at fronto-central sites. An emotion specific N230 at posterior sites to happy, fearful, sad, angry, and surprised compared to neutral faces was reported by Balconi and Pozzoli (2003).

Interpretation of these data is straightforward as long as this is done in a static framework of 'basic emotions'. If done so, the results clearly indicate emotion specific processing of facial expressions as early as 200 ms after stimulus onset.

Facial expressions, however, differ not only in respect to the kind of emotion, but also in respect to saliency, that is, how intense a particular emotion is displayed. Given, that ERP responses reflect both kinds of information, the question arises, where and when is this information processed? Existing ERP literature cannot answer this question beyond pure speculation, since intensity in facial expressions has never been controlled for, reported ERP effects therefore could either indicate emotion specific processing, or processing of intensity, or a mixture of both.

To address this neglected issue, the present study aims to investigate the effect of different intensities of emotional facial expressions on ERPs. In addition, by using the neuropsychologically well-researched basic emotions fear, disgust, and anger, the study also aims to look for ERP components associated with cognitive processing within emotion specific face recognition systems.

2. Methods

2.1. Participants

Sixteen healthy participants (6 female, 10 male) free of neurologic and psychiatric disorders gave written informed consent to take part in the study. The mean age of the participants was 27.7 years (S.D. 6.7). All subjects had normal or corrected-to-normal vision and received payment for their participation (£10). Participants were randomly chosen from a healthy population, resulting in more male than female participants. Since we were investigating general aspects of emotion processing and not concerned about and interested in any gender differences, all participants were included in the analysis without balancing for gender.

2.2. Stimuli and apparatus

The stimuli were presented on a CRT Monitor controlled by a personal computer. Responses were recorded using two buttons mounted horizontally 10 cm apart on a response panel in front of the participant. Left and right key press responses were made with the index fingers of the left and right hand, respectively. The stimuli were computer-manipulated photographs of three different facial expressions (anger, disgust, and fear) varying in intensity (50%, 100%, 150%). These expressions were posed by each of eight models (four females, four males). All stimuli used were taken from the FEEST (for more and detailed information, see Young, Perrett, Calder, Sprengelmeyer, & Ekman, 2002). Viewing distance was held constant at 1 m (Fig. 1).

2.3. Procedure and design

The experiment started with a practice block (36 trials) followed by 10 experimental blocks (with 72 trials in each block). Participants were asked to respond to the gender of the face stimulus presented on the screen. Half of the participants pressed the left key for female and the right key for male faces, the other half received the reverse mapping. A trial started with the presentation of a fixation cross for 500 ms, followed by the face stimulus, which was presented until a response was made. 1500 ms after a response was registered the next trial started. Face stimuli were presented individually and in random order.

2.4. Electrophysiological recordings

Using a BIOSEMI Active-Two amplifier system electroencephalographic (EEG) activity was continuously recorded from 70 Ag/AgCl electrodes including electrodes for recording of horizontal and vertical eye movements. Two additional electrodes (common mode sense (CMS) active electrode and driven right leg (DRL) passive electrode were used as reference and ground electrodes, respectively; cf. www.biosemi.com/faq/cms&drl.htm). EEG and EOG recordings were sampled at 256 Hz. Off-line, the continuous EEG record