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SCIENCE DIRECT
Brain and Cognition 60 (2006) 176–186
Brain and Cognition
www.elsevier.com/locate/b&c

Hemodynamic and electrophysiological relationship involved in human face processing: Evidence from a combined fMRI–ERP study

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Accepted 21 November 2005
Available online 4 January 2006

Abstract

Functional magnetic resonance imaging (fMRI) and event-related potential (ERP) experiments were conducted in the same group of subjects and with an identical task paradigm to investigate a possible relationship between hemodynamic and electrophysiological responses within the brain. The subjects were instructed to judge whether visually presented stimuli were faces or houses and then press the corresponding button. Functional MRI identified face- and house-related regions in the lateral and medial part of the fusiform gyrus, respectively, while ERP showed significantly greater N170 negativity for face than for house stimuli in the temporo-occipital electrodes. Correlation analysis between the BOLD signal in the fusiform gyrus and ERP parameters demonstrated a close relationship between the signal and both latency and amplitude of N170 across the subjects. These correlations may indicate that the variation in cognitive demand and hemodynamic responses during the face/house discrimination task is coupled with the variation of N170 peak latency/amplitude across the subjects. Thus, integrative analysis of spatial and temporal information obtained from the two experimental modalities may help in studying neural correlates involved in a particular cognitive task.

Keywords: Fusiform gyrus; Correlation; N170; Latency; Amplitude

1. Introduction

Multimodal data acquisition and analysis are important strategies for the investigation of higher brain function in the field of cognitive neuroscience. Functional magnetic resonance imaging (fMRI) provides fine spatial information about neuronal activity during cognitive tasks, and event-related potential (ERP) experiments can measure electrophysiological changes in the brain with high temporal resolution. Integrative analysis of spatial and temporal information associated with a particular cognitive function can be achieved by combining these two experimental modalities. Several studies have used a combined fMRI and ERP experiment in the same group of subjects and the same task paradigm to test hypotheses pertaining to auditory attention (Horovitz, Skudlarski, & Gore, 2002; Menon, Ford, Lim, Glover, & Pfefferbaum, 1997; Opitz, Rinne, Mecklinger, von Cramon, & Schroger, 2002), visual attention (Ullsperger & von Cramon, 2001), and face recognition (Horovitz et al., 2002; Puce et al., 2003). Thus, a combination of these two methods for non-invasive examination of the brain and cognition in human subjects seems to be promising; however, the relationship between the blood oxygen level dependent (BOLD) signal obtained by fMRI and the amplitude or latency of the waveform measured by ERP is still unclear.

The neurophysiological basis of the fMRI signal (Logothetis, Pauls, Augath, Trinath, & Oeltermann, 2001; Ogawa et al., 1992) and electroencephalograph (EEG)

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0278-2626/$ - see front matter
doi:10.1016/j.bandc.2005.11.004

(Kutas & Dale, 1997) has been extensively investigated; however the precise mechanisms involved in the transformation of neuronal activity to a BOLD signal or EEG waveform have not been fully elucidated. The hemodynamic responses measured by fMRI fluctuate in a matter of seconds, much more slowly than those monitored by EEG, and are thought to reflect local changes in oxy- and deoxyhemoglobin concentration (Logothetis et al., 2001; Ogawa et al., 1992). On the other hand, EEG waveforms have originated from the synchronized activity of neurons underlying the electrodes on the scalp, and their amplitude is substantially influenced by both the depth of the generator and the orientation of the dipole. Although recent evidence suggests that the BOLD signal has a tighter correlation with local field potentials than with multiunit spiking activity (Logothetis et al., 2001), the manner in which the results of fMRI and those of ERP are integrated in studies on brain activity under a particular task condition is still unclear. To investigate these issues, we adopted a combined fMRI and ERP study and a face/house discrimination task in which the subjects were required to judge whether a visually presented stimulus was a face or a house and then respond by pressing the corresponding button. Although the fMRI and ERP sessions were conducted separately, an identical task paradigm with a different set of stimuli was used, and the order of the sessions was counterbalanced across the subjects. In each session, the run was repeated twice with a randomly intermixed stimulus.

Face stimuli have been shown to elicit clear and large negative deflections in ERP at around 170 ms after the stimulus onset; these deflections are known as the "N170" component (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Sagiv & Bentin, 2001). The N170 component is related to the detection and/or structural encoding of a face that is likely to be mediated by the ventral temporal cortex (Caldara et al., 2003; Itier & Taylor, 2002; Jemel, George, Olivares, Fiori, & Renault, 1999; Schweinberger & Burton, 2003; Schweinberger, Pickering, Jentzsch, Burton, & Kaufmann, 2002). However, several other authors suggest that the source of N170 is located in the lateral part of the temporal lobe (Henson et al., 2003; Itier & Taylor, 2004; Puce et al., 2003). The results of intracranial recordings in epileptic patients indicated that there were two major areas involved in face processing: one in the ventral region including the fusiform gyrus and the other in the lateral region located in the middle temporal gyrus (Allison, Puce, Spencer, & McCarthy, 1999; McCarthy, Puce, Belger, & Allison, 1999; Puce, Allison, & McCarthy, 1999). Furthermore, single cell recordings in monkeys showed that neurons that responded to face stimuli were found both in the superior temporal sulcus and in the inferior temporal gyrus (Rolls, 1992). Therefore, it is still unclear whether N170 originates in the ventral or lateral temporal region or in both of them.

Functional MRI studies have consistently shown that viewing face stimuli activates the lateral part of the fusiform gyrus whereas, viewing houses activates the parahippocampal gyrus and the medial part of the fusiform gyrus (Epstein & Kanwisher, 1998; Gorno-Tempini & Price, 2001; Hadjikhani et al., 2004; Kanwisher, McDermott, & Chun, 1997; Maguire, Frith, & Cipolotti, 2001). On the other hand, some authors (Henson et al., 2003; Puce et al., 2003) have indicated that the lateral temporal region is involved in face processing. These discrepancies with regard to the localization of neural activity and the source of evoked potentials may be attributed to the fact that the BOLD signals and the evoked potential were measured in separate groups of subjects. Therefore, we considered that investigation of a correlation between the data sets obtained from fMRI and ERPs in the same group of subjects would help in resolving these issues. Thus, one goal of the present study is to examine the functional relationship between the BOLD signal and ERP parameters using a combined event-related fMRI and ERP experiment and a face/house discrimination task. We conducted an fMRI subtraction analysis and a comparison of the grand mean waveforms of the N170 component between the face and house conditions. The N170 parameters were then entered into a simple regression analysis to test whether these values correlated with the BOLD signal within the temporo-occipital lobes. We predicted that the N170 amplitude would correlate with the magnitude of the BOLD signal in the temporo-occipital areas under the face condition or the face condition with the house condition variance removed.

2. Methods

2.1. Subjects

Twelve right-handed healthy subjects (six males, mean age ± *SD*, 20.8 ± 1.6 years) participated in the experiment after providing written informed consent. This study was approved by the ethics committee of the National Institute for Physiological Sciences.

2.2. Experimental procedure

Digitized grayscale pictures of 50 faces with neutral expressions taken from posers (25 male and 25 female) and pictures of 50 houses created using computer graphics software (Aska-Pro, Logic, Japan) served as the stimuli (Fig. 1). These pictures were divided into two sets of stimuli that were assigned to each of the fMRI and ERP sessions. The luminance of the pictures was equated. In each run, 25 faces, 25 houses, and 25 null events with fixation were randomly presented to the subject one at a time with 500 ms duration and 4500 ms interstimulus interval. During the interval, a fixation point was always shown. As a warning, the color of the fixation point turned from black to red 400 ms before stimulus onset. The subject was required to not blink while the red fixation point and experimental stimuli were on the screen.

The stimuli were projected onto the transparent screen hanging on the bore of the magnet that was placed