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Amygdala activation and facial expressions: Explicit emotion discrimination versus implicit emotion processing

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Abstract

Emotion recognition is essential for social interaction and communication and is a capacity in which the amygdala plays a central role. So far, neuroimaging results have been inconsistent as to whether the amygdala is more active during explicit or incidental facial emotion processing. In consideration of its functionality in fast automatic evaluation of stimuli and involvement in higher-order conscious processing, we hypothesize a similar response to the emotional faces presented regardless of attentional focus. Using high field functional magnetic resonance imaging (fMRI) specifically optimized for ventral brain regions we show strong and robust amygdala activation for explicit and implicit processing of emotional facial expressions in 29 healthy subjects. Bilateral amygdala activation was, however, significantly greater when subjects were asked to recognize the emotion (explicit condition) than when required to discern the age (implicit condition). A significant correlation between amygdala activation and emotion recognition, but not age discrimination performance, emphasizes the amygdala's enhanced role during conscious emotion processing.

Keywords: Facial emotion recognition; Task modulation; Attention; High-field fMRI

1. Introduction

The ability to correctly recognize emotions in facial expressions plays an essential role in social communication and, evolutionarily, is important for survival (Darwin, 1872). The neural basis of facial emotion processing includes a network of cortical and subcortical structures, centering on the amygdala (Adolphs, 2002; Adolphs, Gosselin et al., 2005; LeDoux, 1995; Morris, Öhman, & Dolan, 1999).

Growing evidence supports the notion that the amygdala is essential for several domains of emotional behavior, such as fear conditioning (Blair, Sotres-Bayon, Moita, & LeDoux, 2005), emotional memory (Adolphs, Tranel, & Buchanan, 2005), mood induction (Habel, Klein, Kellermann, Shah, & Schneider, 2005) and emotion discrimination (Gur, Schroeder et al., 2002). Amygdala dysfunction has been investigated in brain lesion (Adolphs, Gosselin et al., 2005; Adolphs, Tranel et al., 2005) and psychiatric patients (Kohler et al., 2003; Surguladze et al., 2004; Townshend & Duka, 2003). The amygdala's functionality in the early phases of processing is suggested by rich cortical afferents from sensory cortices and fast input routes via the thalamus, as well as extensive output routes to prefrontal and other cortical and subcortical areas. The amygdala's input provides both highly processed and raw information sufficient to prompt fast automatic responses. Accordingly, the amygdala has been considered "the gateway to the emotions" (Aggleton & Mishkin, 1986). Its role has been implicated in evaluating whether a stimulus is pleasant or unpleasant, harmless or dangerous, with a focus on facial expressions of emotions as particularly relevant

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sources of information (see Hariri, Tessitore, Mattay, Fera, & Weinberger, 2002).

Given this functionality, the amygdala should be responsive to all facial expressions of emotion, regardless of whether or not attention is directed toward emotional aspects. This hypothesis has elicited only limited testing with neuroimaging tools and with quite contradictory results. Several studies reported stronger activation of the amygdala-hippocampal area during unattended emotion processing, that is, implicit or passive (gender or age discrimination), compared to explicit tasks (emotion recognition or positive/negative discrimination), in which the depicted emotion was the focus of attention (Critchley et al., 2000; Hariri, Bookheimer, & Mazziotta, 2000; Keightley et al., 2003; Lange et al., 2003). The opposite, however, has also been found: no activation during implicit processing of disgusted faces (Gorno-Tempini et al., 2001) or less activation during incidental emotional processing compared to explicit emotion recognition (Gur, Schroeder et al., 2002). Winston, O'Doherty, and Dolan (2003) presented two faces at a time and asked subjects to either identify the more emotional (explicit condition) or more male face (implicit condition). Task independent amygdala responses were found when high- and low-intensity expressions were compared across four emotions. This study did not, however, require subjects to actually perform emotion identification. Furthermore, an interaction between valence and attention has also been reported (Williams, McGlone, Abbott, & Mattingley, 2005), with stronger activation to unattended, potentially threatening facial stimuli, in contrast to attended stimuli, whilst responses to happy faces were greater when attended. Some of this divergence may be attributed to methodological issues. Most studies applied low-resolution measurement methods, which exacerbate susceptibility-related signal dropout (Merboldt, Fransson, Bruhn, & Frahm, 2001)—particularly affecting the amygdala. Furthermore, most studies used a block presentation design, which is particularly vulnerable to habituation (i.e. Büchel, Dolan, Armony, & Friston, 1999) and movement artifacts (Robinson & Moser, 2004). The choice of analysis approaches may also affect results given the small signal changes in fMRI. Finally, implicit tasks of gender or age discrimination with a binary division of stimuli (male/female and younger/older than 30) and positive/negative decisions are usually much simpler than tasks assessing emotion recognition ability, and task complexity might disengage emotion processing. The present study was designed to address these issues. We used a high-resolution data acquisition (Echo-Planar-Imaging, EPI) protocol specifically developed for imaging the amygdala region at 3 T, to reliably detect BOLD (blood-oxygen-level-dependent) based activation changes (Robinson, Windischberger, Rauscher, & Moser, 2004; Robinson et al., 2005). In particular spatial resolution, slice orientation and echo time were optimized for the high field strength and ventral brain region, giving measurements that yield 60 percent higher time-series signal-to-noise ratio (SNR) in the amygdala than measurements with standard EPI parameters. The effects of physiological artifacts have been compensated for in post-processing, increasing sensitivity. An event-related presentation design was used, which is more flexible and more robust against scanner drifts and head motion. The stimulus material has been pre-validated, and the implicit task has been re-designed to be more demanding and engaging. Whole-brain analysis has been supplemented by ROI approaches. With these methodological improvements we attempted to examine the extent to which the attentional focus of the task – implicit or explicit emotional processing – influences neural activation in the amygdala.

2. Methods

2.1. Subjects

Fourteen right-handed healthy females (mean age 24.2 years, $SD = 4.09$, range 20–35) and 15 right-handed healthy males (mean age 26.9 years, $SD = 2.85$, range 23–33), all Caucasians, participated in the study. All gave written informed consent according to procedures approved by the local ethics committee and the Helsinki declaration. Exclusion of psychiatric disorders (according to DSM IV) was ascertained by the Structured Clinical Interview (German Version of the SCID). The usual exclusion criteria for MRI were applied.

2.2. Tasks and stimuli

In total 42 colored Caucasian facial identities depicting five basic emotions (happiness, sadness, anger, fear and disgust) and neutral expressions were presented—30 for explicit and 12 for implicit emotion recognition. The facial expressions used for the study (for age as well as emotion discrimination) were both selected from a standardized stimulus set (Gunning-Dixon et al., 2003; Gur, Sara et al., 2002) that was comparable with respect to gender, age, emotion intensity, emotional valence, and brightness.

Stimulus presentation was randomized with regard to task, emotion and gender but kept constant for all subjects. Emotional facial expressions were presented for a maximum of 5 s with a randomized, variable inter-stimulus interval ranging from 12 to 18 s. A scrambled face with a central crosshair served as baseline. Responses triggered immediate progression to the next baseline period.

In the explicit task subjects had to select which emotion was portrayed from two alternatives presented verbally on the right and left of the face using a two-button response device. The implicit task was to judge which of two age decades was closer to the poser's age (see Fig. 1 for examples of tasks and discrimination accuracy). To prevent possible habituation effects, different faces depicting emotional expressions were used for age discrimination. However, they were taken from the same stimulus pool to maximize the similarity of the tasks. Explicit and implicit trials were randomly distributed and presented in an event-related paradigm in one single run. Furthermore, each actor appeared only once, hence order effects for identities or emotions were controlled.

2.3. MRI acquisition and data analysis

Functional imaging was performed at 3 T using high-resolution gradient-recalled echo planar imaging (EPI). Ten oblique axial slices centered on the amygdala were acquired using asymmetric *k*-space sampling (matrix size 128 × 91, slice thickness 2 mm, slice gap 0.5 mm, TR = 1,000 ms, TE = 31 ms). Cardiac action and breathing were digitally recorded to allow physiological artifact correction in post-processing (Windischberger et al., 2002; Windischberger, Kilzer, & Moser, 2004) using software developed in-house, based on the algorithms PHYSIOFIX (Hu, Le, Parrish, & Erhard, 1995) and RETROICOR (Glover, Li, & Ress, 2000). In a recent study we quantitatively compared the performance of these algorithms investigating a variety of "flavours" (Kilzer, Windischberger, & Moser 2003) and the variant that performed best was applied in this study.

Functional data were preprocessed using SPM2 (http://www.fil.ion.ucl.ac.uk/spm/). Images were slice timing corrected, realigned to the mean image, normalized into the standardized stereotactic space, and spatially smoothed (9 mm isotropic Gaussian kernel). Functional data were corrected for physiological artifacts using the physiofix and retroicor algorithms as described