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Modulation of the neural network involved in the processing of anger prosody: The role of task-relevance and social phobia

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Abstract

Individuals with social phobia display neural hyperactivation towards angry facial expressions. However, it is uncertain whether they also show abnormal brain responses when processing angry voices. In an event-related functional magnetic resonance imaging study, we investigated brain responses to neutral and angry voices in 12 healthy control participants and 12 individuals with social phobia when emotional prosody was either task-relevant or task-irrelevant. Regardless of task, both phobic and non-phobic participants recruited a network comprising frontotemporal regions, the amygdala, the insula, and the striatum, when listening to angry compared to neutral prosody. Across participants, increased activation in orbitofrontal cortex during task-relevant as compared to task-irrelevant emotional prosody processing was found. Compared to healthy controls, individuals with social phobia displayed significantly stronger orbitofrontal activation in response to angry versus neutral voices under both task conditions. These results suggest a disorder-associated increased involvement of the orbitofrontal cortex in response to threatening voices in social phobia.

Keywords: Phobia; fMRI; Emotion; Threat; Attention

1. Introduction

Individuals suffering from social phobia (SP) are excessively concerned about being negatively evaluated by others. Therefore, the hallmark of social phobia has been characterized as ‘‘a marked and persistent fear of social or performance situations in which embarrassment may occur’’ (APA, 2000, p. 450). Etiological models suggest that information-processing biases play a central role for the development and maintenance of the disorder (Beck et al., 1985; Clark and Wells, 1995). Indeed, it has been shown that individuals with SP display an increased sensitivity towards social cues of disapproval by others (for reviews see Heinrichs and Hofman, 2001; Hirsch et al., 2006). Consistent with this notion, functional imaging studies have repeatedly revealed enhanced neural activity to negative facial expressions, such as anger, contempt, disgust, or fear, in socially phobic compared to non-phobic individuals (Amir et al., 2005; Phan et al., 2006; Stein et al., 2002; Straube et al., 2004, 2005; Yoon et al., 2007). Interestingly, there is also initial evidence that brain activation towards threatening faces in social phobics differs most profoundly from healthy controls when facial emotional expressions are task-irrelevant, suggesting an automatic processing of facial anger cues in social phobia (Straube et al., 2004).

Although angry facial expressions are beyond doubt a prominent social cue to reveal a person’s disapproval of others, corresponding inferences can also be drawn based on other, non-facial social cues, such as human voices. Surprisingly though, altered neural processing of interpersonal threat cues in social phobia has not yet been investigated with other

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expressive social signals than faces. It is well known, however, that whenever listeners perceive human voices they simultaneously process variations in duration, amplitude, pitch contour, tempo, and loudness of an utterance. These prosodic features are powerful signals during interpersonal contact since they enable the reliable discrimination and identification of a speaker's emotional state (Banse and Scherer, 1996; Frick, 1985). Angry voices, in particular, signal rejection and threat similar to angry faces (Banse and Scherer, 1996; Frick, 1985).

The neural network underlying the processing of emotional prosody has been studied intensively in previous studies. Originally, the comprehension of emotional prosody has been claimed to be a special domain of the right hemisphere (e.g., Ross, 1981), but growing evidence indicates that a network spatially distributed across both hemispheres contributes to the appropriate comprehension of emotional prosody (e.g., Adolphs et al., 2002; Imaizumi et al., 1997; Kotz et al., 2003; Schirmer and Kotz, 2006; Wildgruber et al., 2005). Above all, a bilateral fronto-temporal pattern of brain activation has been shown to be associated with processing emotional prosody from normal speech (Kotz et al., 2003). While it is assumed that the superior temporal region serves as an input region mainly involved in the fast analysis of acoustic features, subsequent processes which are more complex and integrative in nature such as labelling the affective tone and/or retrieving its reward value, are thought to be accomplished by bilateral frontal brain regions (Ethofer et al., 2006; Hornak et al., 1996; Wildgruber et al., 2004, 2005; Kotz et al., 2003). Additionally, lesion studies suggest that not only damage to the temporal (Adolphs et al., 2002) and the orbitofrontal cortex (OFC, Hornak et al., 2003) is likely to impair the discrimination of emotional prosody, but also lesions of the basal ganglia (Cancelliere and Kertesz, 1990; Peper and Irle, 1997), and the amygdala (Scott et al., 1997, but see Adolphs and Tranel, 1999; Anderson and Phelps, 1998).

In line with these findings from lesion studies, the comprehension of anger prosody has been shown to rely on a neural network including the striatum (Calder et al., 2004), the rolandic operculum/insula region (Kotz et al., 2003), the amygdala (Sander et al., 2005; Scott et al., 1997), the superior temporal sulcus (STS, Grandjean et al., 2005) and the OFC (Sander et al., 2005). Initial evidence suggests that some areas such as the STS and the amygdala respond to anger prosody even when voices have to be ignored while the OFC seems to show increased activation when attention is focused to the utterances (Sander et al., 2005). Even more interestingly, there is also first evidence that the OFC response to anger prosody is correlated with interindividuell differences in proneness to anxiety reactions in general (Sander et al., 2005). Hence, although the neural network in the perception of anger prosody has not yet been investigated in individuals suffering from social phobia, it appears to be likely that an increased sensitivity towards cues of disapproval might be reflected in increased orbitofrontal activation during the comprehension of anger prosody.

Based on the above findings, the present study investigated the role of task-relevance of prosodic information and social phobia on brain activation to angry compared to neutral utterances. It was hypothesized that social phobia is associated with hyperactivation to angry prosody in the OFC, since OFC activation towards angry voices has formerly been shown to correlate with proneness to anxiety reactions in healthy controls (Sander et al., 2005). In addition, given earlier neuroimaging studies targeting angry facial expressions (Phan et al., 2006; Stein et al., 2002; Straube et al., 2004, 2005; Yoon et al., 2007), we also examined whether individuals with SP would show enhanced responses towards angry utterances in areas such as the insula and the amygdala. Finally, by means of task instructions we investigated whether task-relevance of emotional prosody affects differences in brain activation between socially phobic and non-phobic individuals. Compared to healthy controls, we expected individuals with SP to show increased brain responses especially under conditions in which emotional prosody is task-irrelevant. The latter result would support models assuming automatic biases in the processing of phobia-related cues.

2. Methods and materials

2.1. Participants

Twelve Caucasian participants diagnosed with generalized social phobia (SP) and 12 Caucasian volunteers free of any psychiatric symptoms (healthy controls, HC) took part in the experiment. SP and HC were matched for age [HC = 24.00 vs. SP = 23.25, $t(22) = .58$, $P > .05$], gender (six men and six women per group) and level of education (student population only). All participants provided written informed consent for this study. The study was approved by the Ethics Committee of the University of Jena. For participation in the study, six Euro per hour were paid to all individuals. Participants were recruited by public announcement to the university student population and were required to be right-handed as determined by the Edinburgh Handedness Inventory (Oldfield, 1971). All participants underwent a structured psychiatric clinical interview for diagnosis of DSM-IV Axis I disorders by an experienced interviewer (SCID, Wittchen et al., 1997). Exclusion criteria were (1) a diagnosis of panic disorder or agoraphobia, obsessive–compulsive disorder, current alcohol or substance abuse, psychotic disorder or dementia; (2) a history of seizures or head injury with loss of consciousness; (3) a severe uncontrollable medical condition; (4) the use of any psychotropic medication in the preceding 6 months; and (5) primary or secondary major depression. Individuals with social phobia were diagnosed with primary social phobia of the generalized subtype according to the DSM-IV criteria. Participants with social phobia did not meet criteria for any other current Axis I diagnosis but specific phobia (which happened to be the case in four individuals). All individuals completed two self-report measures: the Social Phobia Inventory (SPIN; German version, Stangier and Steffens, 2001) and the Beck Depression Inventory (BDI; German version, Hautzinger et al., 1995). Individuals suffering from SP scored higher on the SPIN relative to HCs [SP = 39.75 (5.34) vs. HC = 9.67 (5.91), $t(22) = 13.07$, $P < .05$]. BDI-scores were also increased in SP compared to HC [12.5 (4.89) vs. 3.92 (4.32), $t(22) = 4.56$, $P < .05$]. However, BDI-scores of socially phobic individuals were far below the clinical cut-off score of 18 which is considered to indicate the presence of clinically relevant depression (Beck et al., 1981).

2.2. Stimuli

A pilot study was conducted to select words considered to be semantically neutral and non-arousing by consensus of opinion. Twenty-one volunteers from the university's student body were asked to rate 89 words for emotional valence and arousal. All words were bisyllabic German nouns, consisting of five letters each. Ratings of valence and arousal were made on seven-point Likert scales