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Cortical activation during auditory elicitation of fear and disgust: A near-infrared spectroscopy (NIRS) study

Angelika Köchel*, Florian Schöngassner, Anne Schienle

Department of Clinical Psychology, University of Graz, Austria

HIGHLIGHTS

- Fear-relevant sounds led to increased activation of temporo-parietal regions.
- Hemodynamic responses to disgusting sounds are smaller compared to fear.
- Differential neuronal sensitivity to auditory fear and disgust elicitors.

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ABSTRACT

This near infrared spectroscopy study investigated whether nonverbal human sounds representing different basic emotions are able to specifically modulate temporo-parietal cortices, involved in auditory processing and attention. Forty-three adults (19 females and 24 males) were presented with sounds from the categories fear, disgust, and neutral. The stimuli were able to elicit the target emotions with sufficient specificity. The listening to fear-relevant sounds (e.g., screams of fear and pain) led to increased activation of the right superior temporal gyrus and the bilateral supramarginal gyrus. The hemodynamic responses to disgusting sounds (e.g., sniffing, diarrhea) were smaller. Our findings point to a differential neuronal sensitivity of the human brain to two basic emotion elicitors in the auditory domain.

Introduction

Visual stimuli of high motivational relevance compared to neutral stimuli provoke increased activation of (extra) striate and parietal cortex areas [2]. The function of this 'motivated attention' effect is to enhance visual detection and discrimination of survival-relevant cues in the environment. In the case of threat signals, this neuronal mechanism helps the individual to quickly initiate adaptive flight and avoidance behaviors [e.g., 7].

However, sometimes warning signals are not available in the visual domain, but are presented acoustically. For example, we hear screams of pain from a person out of eyesight. From a bio-evolutionary standpoint this information should also be processed in a prioritized manner, which would imply that acoustic affective stimuli should trigger enhanced activation of auditory cortex areas.

Interestingly, there are very few neuroimaging studies on emotional modulation effects of auditory cortex activation. The majority of studies focused on affective prosody [e.g., 3, 16]. These investigations demonstrated that relative to a neutral speech melody affectively intoned sentences led to increased recruitment of the superior temporal gyrus (STG). Moreover, different prosodic categories representing basic emotions (e.g. anger, joy) led to distinct spatial activation patterns within the auditory cortex [3]. STG activation was positively correlated with experienced arousal elicited by the affective words [16].

Research on nonverbal affective stimuli is even rarer. Plichta et al. [10] recorded brain activation with functional near-infrared-spectroscopy (fNIRS), while participants were listening to standardized pleasant, unpleasant, and neutral sounds (e.g., cry of a baby, carousel, growl of a dog) selected from the International Affective Digitized Sound System [1]. They observed that (un)pleasant sounds increased primary auditory cortex activation as compared to neutral sounds.

Whether nonverbal human sounds representing different basic emotions are able to specifically modulate temporo-parietal cortices, involved in auditory processing, has not been investigated so far. Previous studies using functional magnetic resonance imaging already identified specific neural substrates for the specific emotions fear and disgust [8,9]. Fearful sounds as well as fearful faces activated the amygdala, while facial expressions of disgust activated the anterior insula and the basal ganglia [8]. The present study was conducted in order to find out, whether not only limbic brain

* Corresponding author at: University of Graz, Institute of Psychology, Department of Clinical and Health Psychology, A-8010 Graz, Austria. Tel.: +43 0316 380 5086; fax: +43 0316 380 9808.
E-mail address: Angelika.koechel@uni-graz.at (A. Köchel).

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regions but also auditory cortex regions are tuned to specifically decode fear and disgust signals.

In the present NIRS study participants were presented with sounds of human origin from two affective (fear, disgust) and a neutral category. We hypothesized that listening to emotion-specific sounds, such as screams of fear or vomiting would lead to distinct activation patterns in such brain regions involved in auditory processing (STG, parietal cortex).

Method

Subjects

Forty-three right-handed adults (mean age = 26.07 years ± 3.59; 19 females and 24 males) participated in the study. All subjects were healthy and non-medicated. They gave written informed consent after the procedure had been explained to them. All procedures were conducted according to the Declaration of Helsinki, and the study was approved by the ethics committee of the University of Graz.

Procedure

The participants listened to 15 human vocal sounds from the categories disgust (e.g., vomiting, diarrhea), fear (e.g. screaming of a woman, screaming of a men), and neutral (e.g., mumbling). The sounds were selected from the International Affective Digitized Sounds System [1] and our own sound collection. They were presented in blocks of 30 s containing 5 sounds of the same emotional category. Within one block the sounds were presented serial without inter-stimulus-intervals. Each acoustic block was followed by a quiet resting phase of 24 s. The entire recording took about 15 min. After this, all sounds were presented again in randomized order and the participants were asked to rate each of them on 9-point scales for intensity of experienced disgust and fear. Moreover, participants were asked to fill out the Questionnaire for the Assessment of Disgust Proneness, QADP [13] and the trait scale of the State-Trait Anxiety Inventory, STAI [5].

Data acquisition and analysis

To assess changes in the cortical concentration of oxygenated and deoxygenated hemoglobin NIRS was used [6]. Data were recorded with a continuous wave system (ETG 4000, Hitachi Medical Co., Japan) using two 4 × 4 optode probe sets with 48 channels (16 photo detectors and 16 light emitters). The probe sets were attached to the head by means of a plastic grid and elastic bands. The sets were placed on the scalp above the left and right frontal and temporal lobes. The second optode of the last row was set to T4 on the right side and to T3 on the left side (see Fig. 1a).

Relative changes in oxygenated and deoxygenated hemoglobin were recorded and then analyzed using a procedure developed by Plichta et al. [11]. This approach follows typical fMRI analyses of the hemodynamic response function (HRF) and is based on the general linear model (GLM). Raw data were *z*-transformed and visually inspected to identify and discard artifacts. Artifacts were defined as values which spread out more than two standard deviations from the mean. Most of these deflections are due to motion artifacts like head movements that induce small optode shifts. On average 1.57 (STD = 0.91) from 15 trials (per subject and optode set) were identified as artifacts.

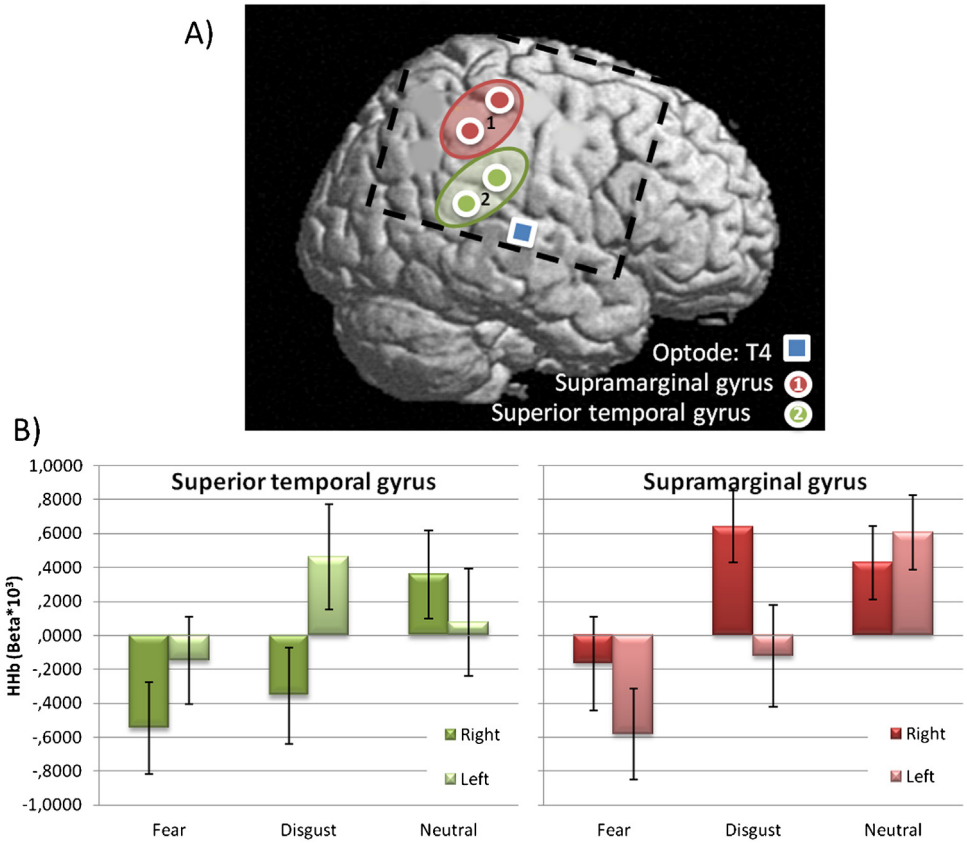

Fig. 1. (a) Area of recorded brain activation and regions of interest; (b) concentration of deoxygenated hemoglobin (HHb; lower beta values indicate stronger activation) during the three sound conditions.