# The insula is not specifically involved in disgust processing: an fMRI study

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fMRI studies have shown that the perception of facial disgust expressions specifically activates the insula. The present fMRI study investigated whether this structure is also involved in the processing of visual stimuli depicting non-mimic disgust elicitors compared to fear-inducing and neutral scenes. Twelve female subjects were scanned while viewing alternating blocks of 40 disgust-inducing, 40 fear-inducing and 40 affectively neutral pictures, shown for 1.5 s each. Afterwards, affective ratings were assessed. The disgust pictures, rated as highly repulsive, induced activation in the insula, the amygdala, the orbitofrontal and occipito-temporal cortex. Since during the fear condition the insula was also involved, our findings do not fit the idea of the insula as a specific disgust processor. *NeuroReport* 13:2023–2026 © 2002 Lippincott Williams & Wilkins.

**Key words**: Disgust; Fear; fMRI; Visual stimuli

## INTRODUCTION

The majority of researchers (e.g. [1]) considers disgust to be a basic emotion with distinctive subjective, physiological, and behavioral response components, such as revulsion, relative heart rate deceleration and the raising of the upper lip together with the nose wrinkle. Especially this last feature could indicate the origin of disgust as a food-related emotion helping the organism to prevent the incorporation of harmful substances or their expulsion [1].

Empirical evidence for the concept of disgust as a basic emotion can be derived from brain imaging studies, which could identify a specific neural substrate of this emotion, namely the insula. In an fMRI study, Phillips *et al.* [2] exposed their subjects to pictures showing faces with disgust and fear expressions. In comparison to neutral faces, fear led to an amygdala activation, whereas disgust stimulated the anterior insular, the medial and dorsolateral frontal cortex, the cingulate, visual cortices (BA 18, 37), the middle and superior temporal gyri, the thalamus, and the putamen. This finding was replicated in a subsequent study [3], where the viewing of prototypical faces displaying disgust led to an activation in the anterior insula, striatal structures (caudate nucleus, putamen, pallidus), occipital and temporal visual areas (BA 18, 37) as well as in temporal gyri (BA 21, 22). The viewing of fear expressions provoked amygdala activation. Similar findings have been obtained by Sprengelmeyer *et al.* [4], who observed an activation of the insula, the orbitofrontal cortex, and the putamen during subjects' perception of disgusted facial expressions, whereas fearful faces stimulated the fusiform gyrus, the dorsolateral and orbitofrontal cortex.

Since in all described studies the experimental task consisted of the viewing of facial expressions, and the subjective disgust responses were not assessed, the role of the insula in disgust processing is not clear yet. This could be assessed using stimuli besides facial expressions, as was done in a recent study by Phillips *et al.* [5]. Here, the subjects (healthy controls and anxiety patients) were presented with pictures displaying disgusting stimuli (e.g. cockroaches, wounds) and neutral contents. The viewing of disgusting scenes led to an increased blood oxygenation in the anterior insula, the cingulate, visual regions (BA 18, 19, 37), the putamen and the cerebellum in both groups.

The present fMRI study also used colored pictures as stimuli displaying a wide variety of different disgust elicitors. As control conditions, we chose fear-inducing as well as neutral scenes. In order to ensure the provocation of intense emotional responses, the scenes were selected from a validated picture set [6] and from the stimulus material of a previous study on disgust [7]. The subjects could simply watch the pictures and were not asked to perform decision tasks as in previous fMRI studies [2–4], which possibly interferes with the emotional processing. Also, the study was restricted to women, since females are characterized by a higher disgust sensitivity than males [1,7].

## MATERIALS AND METHODS

Twelve right-handed female volunteers (mean age 26.3 years; range 21–41 years) participated in the experiment. Exclusion criteria included history of brain injury and current psychiatric illness. No subject was taking regular medication. Informed consent was obtained from the subjects after the nature of the experiment had been explained. Each subject received 25 German marks for the participation.

The stimulus material consisted of 120 pictures [6–7] from three emotional categories: disgust, fear, and neutral, which had been matched for complexity, brightness and color. The disgusting pictures were chosen to represent a broad range of different elicitors, such as disgusting animals (e.g. snails, maggots), bodily deviations/death (e.g. deformed legs, warts, cadavers), poor hygiene (e.g. dirty toilet, garbage piles), unusual food (man eating a grasshopper, man biting into a monkey head), and body products (e.g. excrements, vomit). Fear-inducing pictures showed threatening situations either through attacks by animals (e.g. sharks, lions), attacks by humans (e.g. with knives or pistols) or disasters (e.g. fire, car accident). Neutral scenes consisted e.g. of household articles, geometric figures or nature scenes. Each picture was shown for 1.5 s within a block consisting of 40 pictures of the same category. Within a block the pictures were shown in a randomized sequence. Each block was shown six times during the course of the experiment in a quasi-randomized order with the restriction that no more than two categories of the same type were allowed to follow each other. Pictures were viewed by means of a mirror attached to the head coil (visual field = 18°).

After the picture presentation, subjects rated their impression of the 40 pictures for each category by means of the Self-Assessment Manikin [8] on the dimensions valence, arousal, and dominance. Nine-point Likert scales were used, 9 indicating that the subject felt happy, aroused, and strong. Also, subjects were asked to rate the induced disgust and fear by the picture categories on 9-point scales (1 = not at all; 9 = very strong).

***Image acquisition and analysis:*** Brain images were acquired using a 1.5 Tesla magnetom symphony system (Siemens) with a standard head coil. To minimize movement artifacts, the head of the subjects was fixed to a headholder. A total 366 $T2^*$-weighted images were acquired over 18 min (EPI: TR = 100 ms, TE = 60 ms, matrix: 64 × 64; FOV = 192 mm, 1 s interval between the volumes, $\alpha = 30°$). We recorded from 20 transversal planes with a thickness of 5 m parallel to the AC-PC line covering almost the whole brain (zero gap, interleaved). For the preprocessing and statistical analyses the statistical parametric software mapping (SPM99, Wellcome Department of Cognitive Neurology, London) implemented in Matlab (Mathworks, Inc., Natick, MA, USA, release 12) was used. Origin coordinates were adjusted to the anterior commissure (AC), slice time correction, realignment (sinc interpolation) and normalization to the Talairach space were performed. Smoothing was executed with an isotropic 3D Gaussian filter with a full width at half maximum (FWHM) of 9 mm. A box-car model for the fMRI time series at each voxel was used and contrast images were computed in order to compare activation between the three conditions (disgust, fear, neutral) for each subject. Movement parameters were considered covariates. The contrast images (e.g. disgust > neutral) depict differences in the responses for each subject. Based on these images group statistics were computed in a second level analysis. A one-sample *t*-test was used to assess mean effects. The analyses were carried out in two steps. First an exploratory analysis with a height threshold of $p = 0.01$ (uncorrected) for spatial extent tests (cluster level) was executed. The significance level was set to $\alpha = 0.05$ (corrected for entire volume). Then, based on the described previous findings, we hypothesized that during the disgust condition the insula and putamen would be specifically activated, whereas the fear pictures would provoke amygdala activation. Further, we expected for both affective conditions an increased blood oxygenation in the anterior cingulate, the dorsolateral and orbitofrontal cortex. These directed hypotheses were tested by means of volume of interest (VOI) analyses. The VOI had been defined by the anatomical parcellation of the normalized brain (single-subject high-resolution T1 volume of the Montreal Neurological Institute) as described by Tzourio-Mazoyer *et al.* [9]. With the help of their assignment between anatomical structures and voxel coordinates we created masks, which were used for the VOI analyses. The significance level was set to $\alpha = 0.05$ (corrected for VOI).

## RESULTS

***Subjective ratings:*** Analysis of the subjective ratings showed that disgust could be elicited to a high ($6.8 \pm 2.1$, mean ± s.d.) and fear to a moderate degree ($5.5 \pm 1.8$). The disgusting pictures induced more disgust than fear ($t(11) = 7.6$; $p < 0.001$) and the fear-inducing pictures more fear than disgust ($t(11) = 3.7$; $p = 0.004$). Thus, the target emotions could be elicited specifically. The dimensional judgments indicated that the disgust and fear pictures were comparable with regard to valence (disgust: $2.8 \pm 1.4$; fear: $3.5 \pm 1.6$), arousal (disgust: $5.6 \pm 2.3$; fear: $6.1 \pm 1.9$) and dominance (disgust: $4.3 \pm 1.9$; fear: $3.6 \pm 1.2$). Neutral pictures obtained higher valence and dominance ratings ($p < 0.01$) as well as lower arousal ratings ($p < 0.01$) than the affective pictures.

***Neural responses:*** The exploratory approach revealed two significant activation peaks during the disgust condition compared to the neutral condition. The first cluster peak was located in the right middle occipital gyrus with the surrounding cluster extending in the right and left occipito-temporal cortex, including regions such as the calcarine, the fusiform, and the lingual gyrus as well as the inferior and middle temporal gyrus and parts of the cerebellum. The second cluster peak in the parahippocampal gyrus was part of a cluster restricted to the right hemisphere, containing the amygdala, the hippocampus and the orbitofrontal cortex. Comparing the responses to the fear-inducing with the neutral pictures resulted in a cluster peaking in the right inferior temporal gyrus. The cluster further contained the inferior and middle occipital gyrus, the fusiform and lingual gyrus, the cuneus and parts of the cerebellum. More activation during the disgust condition than during the fear condition was observed in a cluster peaking in the cerebellum. The bilaterally extended cluster included the calcarine, the fusiform, and the lingual gyrus. More fear-specific activation in contrast to disgust occurred in the right middle temporal gyrus. The cluster was restricted to the temporal lobe. Finally, the comparison of neural effects induced by affectively neutral pictures compared to disgusting or fear-inducing scenes showed no significant activation (no suprathreshold clusters). The findings are summarized in Table 1 and Fig. 1.

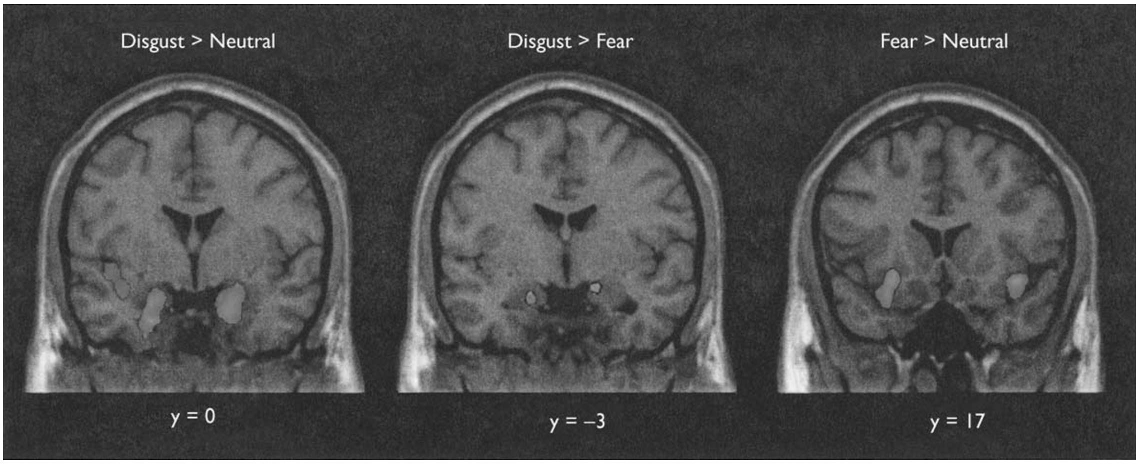


**Fig. 1.** Amygdala activity and insula activity comparing the emotional conditions disgust, fear and neutral.

**Table 1.** Regions, hemisphere, MNI coordinates, number of activated voxels and significance level for the contrast images.

| Region | Side | X | Y | Z | Voxels | *p* |
|---|---|---|---|---|---|---|
| **Disgust > neutral** | | | | | | |
| **Middle occipital gyrus** | **R** | **27** | **−99** | **12** | **4184** | **< 0.0005** |
| **Parahippocampal gyrus** | **R** | **21** | **3** | **−30** | **165** | **0.02** |
| Amygdala (VOI) | L | −18 | −3 | −21 | 12 | 0.002 |
| Amygdala (VOI) | R | 21 | 0 | −21 | 20 | 0.0001 |
| Insula (VOI) | L | −42 | 9 | −15 | 30 | 0.004 |
| Orbitofrontal cortex (VOI) | L | −27 | 33 | −21 | 47 | 0.015 |
| **Fear > neutral** | | | | | | |
| **Inferior temporal gyrus** | **R** | **45** | **−42** | **−24** | **3094** | **< 0.0005** |
| Anterior cingulate (VOI) | L | −9 | 33 | 24 | 17 | 0.017 |
| Dorsolateral prefrontal cortex (VOI) | R | 27 | 45 | 9 | 23 | 0.037 |
| Insula (VOI) | L | −27 | 21 | −12 | 21 | 0.012 |
| Insula (VOI) | R | 42 | 18 | −12 | 15 | 0.026 |
| **Disgust > fear** | | | | | | |
| **Cerebellum** | **L** | **−33** | **−87** | **−24** | **733** | **< 0.0005** |
| Amygdala (VOI) | L | −18 | −3 | −21 | 3 | 0.027 |
| Amygdala (VOI) | R | 18 | −3 | −15 | 2 | 0.05 |
| **Fear > disgust** | | | | | | |
| **Middle temporal gyrus** | **R** | **57** | **−66** | **12** | **225** | **< 0.0005** |

Bold, exploratory analysis; Normal, volume of interest (VOI) analyses: height threshold $p = 0.01$; MNI-coordinates represents the peak of an activated cluster.

The volume of interest analyses indicated that while viewing the disgusting pictures (contrast disgust > neutral) the amygdala was bilaterally involved together with the left insula and left orbitofrontal cortex. During the fear condition (contrast fear > neutral) the left anterior cingulate, the right dorsolateral cortex as well as both insulas were activated. Contrasting the disgust with the fear condition again revealed a bilateral amygdala activation, whereas for the contrast fear > disgust no involvement of the regions of interest could be demonstrated (Table 1).

## DISCUSSION

This study focused on the localization of neural structures critical for the processing of visual non-mimic disgust elicitors using fMRI. The chosen pictures elicited intensely and specifically the target emotion. As predicted, the associated brain activation showed an involvement of the insula, the orbitofrontal cortex and visual occipito-temporal areas. In contrast, we could not identify stronger hemodynamic responses within the putamen, the anterior cingulate and the dorsolateral prefrontal cortex as described in previous studies [2–5]. Unexpectedly, we observed a bilateral amygdala activation during the disgust condition, but not during the fear condition. Therefore, it could be assumed that in our experiment the induced fear was not intense enough to trigger amygdala activation, and that the analysis of the picture material remained a primarily visual one. This hypothesis is in line with the subjective ratings of the fear pictures, indicating that the target emotion was only elicited to a moderate degree. During the fear condition we observed insula activation, a finding which cannot be integrated in the concept of this region as a specific disgust processor [2,3,5]. However, our data are in accordance with a recent meta-analysis on the functional neuroanatomy of emotion [10], demonstrating that the insula is involved in affective tasks without focusing on a specific emotion and therefore can be understood as a limbic integration cortex [11]. A similar concept was described by Damasio [12], suggesting that the insula is part of a central circuit concerned with the monitoring of ongoing internal emotional states (feelings).

The viewing of both negative picture categories in comparison to the neutral scenes was associated with an extended involvement of visual areas with activation peaks in the secondary visual cortices and the ventral visual pathway. Similar activation patterns in occipital regions especially for unpleasant affective visual stimuli have been described before [5,13–15] for normal subjects as well as for patients with anxiety disorders viewing their feared stimuli [5,16]. These findings have been interpreted as an arousal effect, as an effect of stimulus significance, which enhances attention and the processing in the stimulated modality [16]. This interpretation also fits nicely with our data, since the disgust pictures, which had been matched with the fear pictures for physical features, but were experienced as more salient, led to a more extended activation in visual occipito-temporal regions.

Altogether our data clearly speak against the assumption that disgust is specifically processed in the insula. Rather our findings are in line with those approaches assuming that there are affectively relevant brain structures, which are shared by different emotions [12,17]. In one of these models by Rolls [17] a central affective circuit is described, which is concerned with the evaluation of reinforcement contingencies of stimuli. Important structures in this circuit responding to punishment and reward are the amygdala and the orbitofrontal cortex. Exactly these structures were involved in the disgust processing during our experiment.

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