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Research Report

How do we modulate our emotions? Parametric fMRI reveals cortical midline structures as regions specifically involved in the processing of emotional valences

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Abstract

One of the major problems in affective neuroscience of healthy subjects as well as of patients with emotional dysfunctions is to disentangle emotional core functions and non-emotional processes. Emotional valence is considered an emotional key process. The present study employed a parametric functional magnetic resonance imaging (fMRI) study to address this question. Thirteen healthy volunteers were scanned during emotional stimulus processing (International Affective Picture System). The presented pictures covered the entire range of emotional valences. The fMRI data were consecutively subjected to a preliminary categorical (valence-independent) and a detailed parametric analysis, the latter using individual valence ratings as regressor. The parametric analysis revealed a linear valence-dependent modulation of the BOLD signal in the orbito- and dorsomedial prefrontal cortex (OMPFC, DMPFC), medial parietal cortex (MPC), and insula. In addition, we observed that emotional valence exerts its effects predominantly via modulation of signal decreases. We conclude that the psychological concept of emotional valence may be related to neural processing in cortical midline regions.

Theme: Neural basis of behavior
Topic: Motivation and emotion

Keywords: Emotion; Valence; Cortical midline region; Baseline; IAPS

1. Introduction

One of the most pertinent questions in affective neuroscience of healthy subjects as well as of patients with disturbed emotional processing is how specialized functions for emotional operations can be associated with specific brain regions. Besides genuine emotional factors, accompanying factors are unavoidably involved in emotional tasks. These concern, for example, the induction method as well as cognitive functions such as attention, working memory, and evaluation. Since these accompanying factors are difficult to control for, emotional factors of interest may potentially remain masked. In order to isolate emotional functions from rather accidental accompanying non-emotional processes, tasks are needed which exclusively vary emotional attributes of the presented stimuli leaving all the confounding factors of the task as unaltered as possible. In this study, we propose a parametric design, which uses valence modification of emotional stimuli to modulate exclusively regions involved in a core feature of emotional processing, the attribution of emotional valences.

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Since its photographs are validated according to their emotional valence, the International Affective Picture system (IAPS) [33] was considered as the appropriate tool for this investigation. In this system, emotional valence comprises the continuum between negatively and positively rated emotions on a scale from 1–9. The values 1–3 are ascribed to negative, 4–6 to neutral, and 7–9 to positive valences. Numerous previous neuroimaging studies have used IAPS pictures to investigate the neural correlates of emotional processing. No study has up to now used IAPS pictures for parametric analysis of valence processing. However, several IAPS studies employed categorical analyses to investigate valence processing. Contrasting negative, positive, and neutral pictures against each other, these investigations aimed at identifying regions specifically associated with negative or positive valence [29,30,36,44,49,60]. Cortical regions associated with negative emotions include the amygdala, hippocampus, parahippocampal gyrus, occipitotemporal cortex, right caudate, and cerebellum. In contrast, positive emotions were characterized by activation in the dorsolateral prefrontal cortex, left superior temporal cortex, left caudate, putamen, and striatum. In addition, hemispheric asymmetry has previously been suggested. Positive emotions tend to be lateralized towards the left hemisphere, whereas negative emotions have been associated with the right hemisphere mainly [10,12]. However, a substantial overlap between regions involved in positive and negative emotional processing has also been reported. This overlaps concerns besides subcortical regions (e.g., thalamus, hypothalamus, midbrain) especially the orbitomedial prefrontal cortex (OMPFC) [30,31].

The OMPFC seems to play a central role in emotional processing [12,29,50]. A meta-analysis reviewing 55 neuroimaging studies [50] found the OMPFC involved in a variety of emotional paradigms concerning all kinds of emotions such as sadness, happiness, disgust, and fear [10,15,20,22,49,60]. OMPFC involvement is commonly observed during the induction of emotions in different sensory modalities, including visual, auditory, and gustatory [6,29,41,44–47,55,59]. Additionally, various methods of induction of emotional experience (verbal and non-verbal; current external events and recall of past events) lead to involvement of the OMPFC [17,20,24,25,29,52]. It has therefore been suggested that the OMPFC might be implicated in processes that are common to various emotional tasks such as the experiential aspect of emotional processing, emotional regulation, or emotion-driven decision making.

Given this general function of the OMPFC in emotional processing and its engagement in both negative and positive emotional processing, may we assume that neural activation in the OMPFC is independent of the valence of the presented emotional stimulus? A few studies have reported differences in OMPFC activity associated with the processing of positive, neutral, and negative valences [5,20,29,30,36,49,56,60]. Specifically, when contrasting positively to negatively valenced stimuli, they observed signal increases in the OMPFC. Using olfactory stimuli, a recent study by [5] demonstrated valence-dependent modulation of neural activity in the posteromedial orbitofrontal cortex. They observed that the two odors citral and valeric acid are associated with signal changes in the posteromedial orbitofrontal cortex. These signal changes correlated with the evaluation of the pleasantness of the stimuli: The more positive the stimuli were rated, the higher signal intensity was detected in the posteromedial orbitofrontal cortex.

While this was demonstrated for the olfactory system, valence-dependence has not been investigated yet in the case of visual emotional processing. The difference in modality might be crucial. Psychologically, the visual presentation of emotional photographs from the IAPS might contain a richer semantic content than olfactory stimuli. In addition, different modalities might involve distinct neuronal systems in emotional processing. For example, visual emotional stimuli were found to preferentially activate the amygdala and the visual cortex compared to non-visual induction methods [50].

The aim of the present study was to investigate valence processing in the visual modality. Based on abovementioned findings, we expected involvement of the OMPFC in the modulation of emotional valence. Analogously to the results obtained in the OMPFC with olfactory stimuli, we assumed valence-dependent continuous signal changes in the OMPFC. The psychological continuum of emotional valences, as presupposed in the IAPS, should then be mirrored in an analogous continuum of physiological signal changes in the OMPFC. In order to test this hypothesis of continuous valence-dependent signal changes in the OMPFC, we performed a parametric analysis of data acquired in fMRI during visual presentation of emotional stimuli from the IAPS.

2. Methods

2.1. Subjects

We studied 13 healthy subjects (3 women, 10 men; average age: 27.0; range: 23 years to 34 years). They all had at least 16 years of education with achievement of a college degree. The subjects were thoroughly questioned about psychiatric, neurological, or medical diseases as well as the use of psychoactive substances by a psychiatrist (GN) using a custom-made semistructured clinical questionnaire. None of the subjects included in the study had history of axis I disorder, neurological, or severe medical illness. All subjects denied recent substance abuses. All subjects were right-handed as assessed by the Edinburgh Inventory for Handedness. After detailed explanation of the study design and potential risks, all subjects gave written informed consent.