Neuropsychologia 100 (2017) 26–34

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

Don’t worry, be happy - Neural correlates of the influence of musically induced mood on self-evaluation

Sarah Oetken[a,b,*], Katharina D. Pauly[a,b], Ruben C. Gur[c], Frank Schneider[a,b,c], Ute Habel[a,b], Anna Pohl[a,b,1]

[a] Department of Psychiatry, Psychotherapy and Psychosomatics, Medical Faculty, RWTH Aachen University, Pauwelsstr. 30, Aachen, Germany
[b] JARA-Institute Brain Structure Function Relationship, Research Center Jülich and RWTH Aachen, Jülich, Germany
[c] Department of Psychiatry, University of Pennsylvania, USA

A R T I C L E I N F O

Keywords:
Self-evaluation
Self-worth
Mood induction
FMRI
Amygdalo-hippocampal complex

A B S T R A C T

Self-evaluation affects one's own mental state, social interactions and everyday life. Mood, in turn, has an impact on self-evaluation. However, the influence of mood on self-evaluation at the neural level has barely been examined. In this fMRI study, the interaction of mood and self-perception was investigated in 20 healthy participants. Happy, sad and neutral music was presented while participants were instructed to immerse themselves in the mood of the music and to rate how well presented traits characterized themselves. In a lexical control condition, subjects had to count a specific letter in the word. Behavioral data reflected successful mood induction. While self-ascription of positive traits was unaffected by mood, self-ascription of negative characteristics was *decreased* by negative affect. A positive correlation was found between self-worth scores and the difference in the amount of self-ascribed positive versus negative traits during negative mood induction. At the neural level, amygdalo-hippocampal, superior and middle temporal structures were differently involved in self-evaluation (vs. lexical processing) depending on the mood. While activation of the amygdalo-hippocampal complex was found during sad in comparison to both happy and neutral mood, superior/middle temporal gyrus (STG/MTG) activation was only found when contrasting sad vs. neutral mood. Further, a correlation analysis with self-worth ratings revealed a positive relation to STG activation during self-ascription of trait adjectives in sad compared to neutral mood. Our results underscore the importance of the current emotional state for self-evaluation and identify some neural correlates of this effect. Our findings in healthy research participants suggest a compensatory mechanism during sad mood induction to maintain a positive self-image, which is supported by activation of limbic and fronto-temporal cortex. Studies in clinically depressed populations could reveal whether this compensatory mechanism is aberrant.

1. Introduction

Self-evaluation is an important element of self-regulation and people who believe in their capabilities are encouraged to achieve their aims (for a review: MacKenzie et al., 2012). Furthermore, self-evaluation is important for the quality of interpersonal relations. Finally, the association between self-evaluation and social bonds explains health related problems (Stinson et al., 2008). In general, humans tend to rate themselves positively (e.g. Beer et al., 2010); Pauly et al., 2011; Pauly et al., 2013]. However, a negatively biased self-evaluation can result in impaired self-regulation, lower quality of life (Frischknecht et al., 2011) and even in depression (Sowislo and Orth, 2013).

There is a close and reciprocal relation between mood and cognition, and thereby our subjective understanding of the self (Northoff et al., 2009). Self-appraisals result in emotional reactions, which in turn have an impact on subsequent thoughts and behavior (Heatherton, 2011). For example, negative thoughts can cause depressed mood and depressed mood conversely increases the probability for negative cognitions resulting in a vicious circle (Teasdale, 1983). However, despite this evidence of mutual interaction, the interaction of actual mood and self-evaluation has rarely been investigated on the neural level.

Neural correlates of self-evaluation have been extensively addressed in previous studies. Typical activation patterns included cortical midline structures comprising the medial prefrontal cortex (mPFC), ante-

* Corresponding author at: Department of Psychiatry, Psychothera py and Psychosomatics, Medical Faculty, RWTH Aachen University, Pauwelsstr. 30, 52074 Aachen, Germany.
E-mail address: soetken@ukaachen.de (S. Oetken).
[1] Present Address: Department of Clinical Psychology and Psychotherapy, University of Cologne, Albertus-Magnus-Platz, 50923 Cologne, Germany.

http://dx.doi.org/10.1016/j.neuropsychologia.2017.04.010
Received 17 July 2016; Received in revised form 25 February 2017; Accepted 6 April 2017
Available online 07 April 2017
0028-3932/

rior (ACC) and posterior cingulate cortex (PCC) as well as the precuneus (for reviews see van der Meer et al., 2010; Northoff and Bermpohl, 2004; Bermpohl, 2004). According to a model of van der Meer et al. (2010), the demand of self-appraisal enhances self-directed attention, which involves the ACC. Subsequently, external self-relevant properties are coupled with internal affective states in the ventromedial prefrontal cortex (vmPFC) (van der Meer et al., 2010; Northoff et al., 2006). As the vmPFC is involved in emotional processes during self-reflection, this structure seems to be of particular interest in the context of the interaction of self-evaluation and affective states. Self-/other-relevant information is coupled and analyzed in the context of autobiographical memory within the PCC. The vmPFC and PCC pass information on to the insula, which, in turn, is involved in somaesthetic feedback, which has been linked to the "embodied self" (van der Meer et al., 2010). This model is in line with the conclusion of Critchley et al. (2004) that interoceptive feedback is coded in the insula. Finally, the decision whether a certain attribute applies to oneself or another person is related to activation in the dorsomedial prefrontal cortex (dmPFC) (van der Meer et al., 2010; Schmitz et al., 2004).

Northoff et al. (2009) proposed a close relationship between emotional processing and self-related processing in lower brain regions. Several studies investigated self-referential processes by asking participants to evaluate themselves on the basis of valenced trait adjectives. Analyzing valence (positive and negative independently) at a neural level Fossati et al. (2003) found activation of the bilateral mPFC, PCC. Self-evaluation regarding positive in comparison to negative adjectives resulted in increased activation in the right insula, left superior temporal and inferior parietal cortex. Contrary to this, increased involvement of the bilateral amygdala and bilateral insula was found during silent reading of pleasant *and* unpleasant in comparison to neutral words if words were paired with the possessive pronoun my (self-condition). The same held true if this 'self-condition' was compared to an 'other-condition' (i.e. "his" plus word) or to a 'control condition' "the" plus word; (Herbert et al., 2011b). When investigating positive self-evaluation, i.e. activation during the actual self-ascription of positive and the rejection of self-related negative trait adjectives, contrasted to the correct lexical processing of traits, Pauly et al. (2013) reported involvement of the dmPFC, left inferior orbitofrontal cortex, PCC, left angular gyrus, left hippocampus and several temporal areas.

As we were interested in the influence of mood on self-evaluation, we aimed at inducing different affective states experimentally by means of musical pieces. It has been shown that music induces mood rather automatically (Gerrards-Hesse, 1994). Studies that used musical mood induction revealed the involvement of structures associated with emotion processing, mainly (para-) hippocampal areas, the amygdala, the nucleus accumbens and the orbifrontal cortices (for a review see Koelsch, 2010). Other structures that have been related to musical mood induction are the ACC and the insula. Koelsch (2010) argues that the ACC might subserve the synchronization of different processes involved due to its key role in monitoring, motivation, and cognitive as well as emotional control.

In the current study, we investigated the influence of musically induced mood states on self-ascription of trait adjectives and on functional brain networks underlying self-evaluation. We furthermore aimed at investigating the relations between self-worth and brain activation in these networks. At the behavioral level, we expected a shift of self-evaluation in the direction of the presented mood (e.g. less self-ascribed positive trait adjectives and more self-ascribed negative traits during sad mood, and vice versa for happy mood). We expected that this shift of self-evaluation would be smaller in people with higher self-worth. At the neural level, we hypothesized a stronger involvement of prefrontal areas, especially of the ventromedial PFC or the orbitofrontal cortex during self-evaluation in happy or sad (compared to neutral) mood. Relative activation in the amygdala and/or (para-) hippocampus were expected for emotional as compared to neutral music. We expected that increased activation in these regions during self-evaluation in sad mood (versus happy or neutral mood) might be compensatory to maintain a positive self-image. Thus, activation of these regions should be positively related to self-reported self-worth.

2. Materials and methods

2.1. Data acquisition

2.1.1. Participants

Twenty-one healthy volunteers (11 women) participated in the study. One participant had to be excluded from the analyses due to excessive movement within the scanner (see below). Subjects were aged from 21 to 42 years ($M_{age} = 26.5$ years; $SD = 5.51$), right-handed according to the Edinburgh Inventory (Oldfield, 1971) and had normal or corrected to normal vision. According to the German "Wortschatztest" (a multiple choice test for crystalline intelligence developed by Schmidt and Wetzler (1992) participants had an average IQ of 109.60 ($SD = 8.25$). Depressiveness was within normal limits according to the Beck Depression Inventory (German version: Schmitt et al., 2003; $M = 11.45$; $SD = 7.27$). Participants who had been diagnosed with neurological diseases or past or present mental disorders as assessed by the Structured Clinical Interview for DSM-IV disorders [SCID-I; German version by Wittchen et al. (1997)] were excluded from the study. The research project was approved by the ethical review committee of the Medical Faculty of the RWTH Aachen University. All subjects gave their written informed consent and received reimbursement for their participation.

2.1.2. Stimuli

Participants were asked to assess themselves on the basis of visually presented positive and negative trait adjectives. The selection and matching of the stimuli was an adaptation of previous studies addressing emotionally valenced self-evaluation (Pauly et al, 2014). Stimuli encompassed 108 positive and 108 negative German trait adjectives, which did not differ in terms of length (number of letters: $T_{(214)} = 0.52$, $p = 0.607$) or frequency ($T_{(214)} = 0.69$, $p = 0.493$) according to the Celex Lexical Database (Baayen et al., 1993). Furthermore, positive and negative adjectives were matched regarding the rating of their concreteness-abstractness ($T_{(214)} = -0.01$, $p = 0.990$) and imagery ($T_{(214)} = 0.02$, $p = 0.986$) as in the Handbook of German Word Norms (Hager and Hasselhorn, 1994). However, as intended, pleasantness of positive and negative traits differed significantly ($T_{(193.57)} = 60.31$, $p < 0.001$).

Segments of classical music were used for mood induction. A total of 60 classical music excerpts were extracted and cut to a length of 35 s (corresponding to the length of one block during the fMRI measurement). Fifteen adult and 15 adolescent participants rated the excerpts in advance in terms of valence and arousal on a 9-point scale (valence: 0 = very sad to 9 = very happy; arousal: 0 = dozy to 9 = alert). These participants were independent of the fmri sample, as no one was allowed to take part in both studies. Twelve excerpts per mood (sad, happy, neutral) were selected based on the valence ratings. Excerpts with the highest valence ratings were assigned to the happy mood condition ($M = 6.81$; $SD = 0.34$), those with the lowest rating to the sad mood condition ($M = 3.18$; $SD = 0.25$). The excerpts that received a moderate rating were assigned to the neutral condition ($M = 4.89$; $SD = 0.24$). Valence ratings differed significantly among all mood conditions ($F = 495.86$, $df = 35$, $p < 0.001$) and for all post hoc comparisons (all $p < 0.001$ at a Bonferroni-corrected ($p = 0.017$) significance level). Also arousal ratings differed between conditions ($F = 49.884$, $df = 35$, $p < 0.001$; happy: $M = 6.04$, $SD = 1.38$; neutral: $M = 4.28$, $SD = 1.11$; sad: $M = 3.4$, $SD = 1.00$; happy vs. sad $p < 0.001$ happy vs neutral $p < 0.001$; sad vs. neutral $p = 0.008$, all comparisons significant at a Bonferroni-corrected ($p = 0.017$) significance level). After selection of the final stimulus set of 36 pieces in total, a fade-in fade-out effect of 2 s was applied to the recordings (Adobe® Audition®1.5) to circumvent