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Implicit emotion regulation in the presence of threat: Neural and autonomic correlates

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ABSTRACT

Efficient emotion regulation is essential for social interaction and functioning in human society and often happens without direct intention and conscious awareness. Cognitive labeling of stimuli based on certain characteristics has been assumed to represent an effective strategy of implicit emotional regulation whereas processing based on simple perceptual characteristics (e.g., matching) has not. Evidence exists that the ventrolateral prefrontal cortex (VLPFC) might be of functional relevance during labeling by down-regulating limbic activity in the presence of threatening stimuli. However, it remained unclear whether this VLPFC activation was particularly specific to threat because previous studies focused exclusively on threatening stimuli. In the current study, 35 healthy participants labeled or matched both threatening and neutral pictures while undergoing 52-channel functional near-infrared spectroscopy. Results showed increased VLPFC activation during labeling of threatening but not neutral pictures. No increase in prefrontal activation was detected during matching. Moreover, skin conductance increased equally for both valence conditions during initial phases of labeling whereas during matching stronger increases were found for threatening stimuli. Although a general inverse relationship between VLPFC function and skin conductance was not confirmed, both were negatively correlated during matching of threatening pictures in subjects with high state anxiety. It was concluded that the VLPFC plays an essential role during implicit emotion regulation. Further, even simple perceptual processing seems to engage regulatory top-down activation in anxious individuals.

Introduction

Emotion regulation refers to the ability to handle distressing or inappropriate feelings by using appropriate emotion regulation strategies. The most frequently mentioned strategies in this context include reappraisal and suppression or distraction (Gross, 2002; Kalisch et al., 2006) while reappraisal appeared to be the most effective one (Gross and John, 2003; John and Gross, 2004). However, emotion regulation does not necessarily require conscious awareness and can occur without insight. Gyurak et al. (2011) differentiated between these two kinds of emotion regulation, as being either explicit or implicit. While reappraisal and suppression represent strategies of explicit emotion regulation, other strategies are applied implicitly and occur outside of awareness without conscious intention. As an example, the authors refer to affect labeling as a cognitive strategy of implicit emotion regulation.

Labeling has been initially investigated in two functional magnetic resonance imaging (fMRI) studies to differentiate between the neural correlates of simple perceptual compared to more elaborate cognitive processing (Hariri et al., 2000, 2003). In these studies, the authors presented threatening visual stimuli (i.e., angry/fearful faces or threatening pictures) to healthy subjects. Subjects either matched the presented target picture to one of two simultaneously presented pictures of which one was identical to the target or they labeled the according picture with one of two possible descriptions referring to the meaning or content of the stimulus. In one study (Hariri et al., 2000), affective labels were used while in the other (Hariri et al., 2003) labels referred to neutral characteristics of the presented picture. However, results were comparable between both studies: Matching threatening stimuli was associated with increased amygdalar and thalamic activation, whereas labeling elicited activations in the VLPFC, anterior cingulate cortex (ACC), and Broca's area. Moreover, activity in amygdala and prefrontal activation was negatively correlated, suggesting that in the presence of threatening stimuli,

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emotional regulation of the subcortical limbic fear response is governed by the PFC (Hariri et al., 2000, 2003). This finding is in line with earlier functional neuroimaging studies that identified the PFC and amygdala as core brain structures involved during emotional regulation (Kim et al., 2011b). As discussed by Lieberman et al. (2007), affect labeling partly resembles reappraisal, although reappraisal was rather associated with activation increases in the right anterolateral PFC (Kalisch et al., 2005), whereas, similar to affect labeling, self-distraction was linked to activation increases in the left lateral PFC (Kalisch et al., 2006). The most important distinction between both processes, however, is that reappraisal refers to explicit emotion regulation, whereas affect labeling represents an implicit emotion regulation process.

While a lot of evidence points towards a regulatory role of the PFC during cognitive emotional regulation, no scientific consensus has been reached with regard to the obligatory unconditional response of the amygdala to emotionally salient stimuli, particularly threatening or fear-related stimuli (Bishop, 2008). Many studies reported a functional connectivity between both structures during emotion regulation (for recent reviews see Gyurak et al., 2011; Kim et al., 2011b). Recent studies showed that a response of the amygdala is more likely to occur following transient emotional provocation but is not sustained over longer periods of emotional stimulation (Alvarez et al., 2011; Somerville et al., 2013). Moreover, activation in the ventromedial prefrontal cortices (VMPFC) was negatively associated with this transient amygdala response (Somerville et al., 2013) and is assumed to have a regulatory function (Etkin et al., 2011). Connectivity between the VMPFC, dorsomedial PFC (DMPFC), and amygdala is also influenced by state anxiety with positive VMPFC–amygdala correlations in low anxious and negative correlations in high anxious individuals at rest. In contrast, low anxious subjects displayed an inverse relationship between the DMPFC and amygdala. Functional connectivity in these areas was also found to correlate with trait anxiety with less pronounced effects (Kim et al., 2011a).

Until today, only few functional imaging studies directly compared simple perceptual bottom-up with more elaborate top-down processing of threatening or fear-relevant stimuli (e.g., Hariri et al., 2000, 2003; Lieberman et al., 2007). It is possible that the effects found in those studies might primarily be due to the higher cognitive load and linguistic demands of labeling compared to matching. The idea that prefrontal activation during affect labeling results from cognitive and linguistic top-down processes has been addressed before in an fMRI study by Lieberman et al. (2007). To solve this problem, the authors varied the labels which subjects had to ascribe to facial stimuli. In the experimental condition, affective labels were presented, whereas, in the control condition gender labels were used. Thus in the first condition, attention was directed at the stimulus meaning and in the second it was directed at affect-independent stimulus properties alone. Their results revealed that affect labeling elicited higher right VLPFC activation than gender labeling and can thus not be due to higher cognitive load per se.

The specificity of VLPFC activation with respect to stimulus valence, however, has never been investigated in detail. Earlier studies used exclusively stimuli of negative valence (i.e., fear, anger, threat) but interpreted their findings as being either specific to the particular valence at hand (Hariri et al., 2000, 2003) or independent of the affective valence at all (Lieberman et al., 2007). The present study aimed at identifying the role of the VLPFC during implicit emotion regulation of particularly threatening stimuli more precisely by using functional near-infrared spectroscopy (fNIRS). To this end, we adapted the original affect labeling paradigm by Hariri et al. (2003) and added additional conditions using neutral pictures to simultaneously investigate the effects of valence (threatening vs. neutral) and to control for the higher cognitive load of the labeling as compared to the matching condition. We aimed at investigating whether VLPFC activation during labeling was due to cognitive picture evaluation alone or specific to implicit regulation of salient emotional stimuli, in this case threatening pictures. Likewise, we assessed whether top-down processing of threatening stimuli leads to lower autonomic responses in terms of skin conductance. We referred to the skin conductance level (SCL) as an indirect measure of amygdalar reactivity because only cortical activation changes can be targeted by using fNIRS. Skin conductance, however, provides a useful measure of limbic function since it has been found to be strongly linked to activation changes in the amygdala (Furmark et al., 1997; Lang et al., 2000). We hypothesized that perceptual processing of threatening compared to neutral pictures elicits an amygdalar reaction which in turn causes SCL increases. In contrast, elaborate cognitive processing of threat during labeling was hypothesized to increase regulatory VLPFC activity, thereby down-regulating the amygdalar response leading to smaller valence effects (threat > neutral) in terms of skin conductance. Based on earlier findings, we assumed an inverse relationship between VLPFC activation and SCL particularly during the presentation of threatening stimuli. This negative correlation was hypothesized to be more pronounced during top-down compared to bottom-up processing and to be stronger in subjects with higher levels of state anxiety.

Methods

Subjects

In total, 37 subjects participated in the current study and filled in the state subscale of the State–Trait Anxiety Inventory (STAI; Spielberger et al., 1970). All except for one were right-handed. Two subjects had to be excluded because one of them reported a history of psychopathology (bulimia nervosa and major depression) and the other repeatedly fell asleep during the measurement. Data of the remaining 35 subjects (mean age: 26.46 years; SD: 6.96; 24 female) were entered into further statistical analyses.

The study was approved by the ethics committee of the University of Würzburg and in accordance with the declaration of Helsinki in its latest revision. All subjects gave written informed consent.

Task

The task was adopted from Hariri et al. (2003) but slightly modified. We selected 36 neutral and 36 threatening pictures of the International Affective Pictures System (IAPS; Lang et al., 1997). Stimuli differed significantly in terms of valence ($\bar{x}_{neutral} = 5.64 \pm .90$, $\bar{x}_{threat} = 3.31 \pm .71$; $t_{(70)} = 12.35$, $p < .001$) and arousal ($\bar{x}_{neutral} = 3.45 \pm .91$, $\bar{x}_{threat} = 6.22 \pm .52$; $t_{(70)} = 15.94$, $p < .001$). The task consisted of two main experimental conditions: matching versus labeling pictures. During the *matching condition*, a target stimulus was presented in the upper half of a computer screen on a black background and two pictures of the same valence condition, of which one was identical to the target, were shown next to each other below the target. During each trial, subjects had to indicate by button press, which picture matched (i.e., was identical to) the target. During the *labeling condition*, a target stimulus was presented in the same way as during the matching condition but instead of two pictures, two labels were given below ('natural' vs. 'artificial'). Subjects were instructed beforehand to judge whether the target picture displayed rather a natural or an artificial scene. Natural scenes were defined as 'something occurring in nature without human influence' and included for example plants, mushrooms, landscapes or animals. Artificial scenes depicted for example tools, traffic or war scenarios and always referred to objects or situations that were 'created or caused by human beings'. Labels were presented in different colors (green for 'natural' vs. orange for 'artificial') and associated with a corresponding button (left and right, respectively) for the entire session to direct attention at picture evaluation and to minimize distraction due to reading. Similar to the original study (Hariri et al., 2003), 20 pictures of geometrical shapes were used as a *control condition* to control for sensorimotor activations during the task. In contrast to the earlier version of the task, shapes were presented in different colors to adjust task difficulty to the match condition because IAPS pictures were presented