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Common and differential neural networks of emotion regulation by Detachment, Reinterpretation, Distraction, and Expressive Suppression: A comparative fMRI investigation

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ABSTRACT

Emotions are an indispensable part of our mental life. The term emotion regulation refers to those processes that influence the generation, the experience and the expression of emotions. There is a great variety of strategies to regulate emotions efficiently, which are used in daily life and that have been investigated by cognitive neuroscience. *Distraction* guides attention to a secondary task. *Reinterpretation*, a variant of cognitive reappraisal, works by changing the meaning of an emotional stimulus. *Detachment*, another reappraisal strategy, refers to distancing oneself from an emotional stimulus, thereby reducing its personal relevance. *Expressive Suppression* modifies the behavioral or physiological response to an emotional stimulus. These four strategies are not equally effective in terms of emotion regulation success and have been shown to partly rely on different neuronal systems. Here, we compare for the first time the neural mechanisms of these typical strategies directly in a common functional magnetic resonance imaging (fMRI) paradigm of downregulation of negative emotions. Our results indicate that three of those strategies (Detachment, Expressive Suppression and Distraction) conjointly increase brain activation in a right prefronto-parietal regulation network and significantly reduce activation of the left amygdala. Compared to the other regulation strategies, Reinterpretation specifically recruited a different control network comprising left ventrolateral prefrontal cortex and orbitofrontal gyrus and was not effective in downregulation of the amygdala. We conclude that Detachment, Distraction and Expressive Suppression recruit very similar emotion regulation networks, whereas Reinterpretation is associated with activation of a qualitatively different network, making this regulation strategy a special one. Notably, Reinterpretation also proved to be the least effective strategy in neural terms, as measured by downregulation of amygdala activation.

Introduction

Emotion regulation is important when emotional responses interfere with important goals, or when they compete with other, socially more adequate responses (Côté et al., 2010; Koole, 2009). Moreover, dysfunction of emotion regulation is a well-known feature of psychiatric conditions (Davidson et al., 2000, 2002; Erk et al., 2010a; Johnstone and Walter, 2014; Kanske et al., 2012; Koenigsberg et al., 2009; Schulze et al., 2010). Emotion regulation depends on efficient cognitive control functions that are able to generate, maintain and adjust sets of goal-directed strategies (Egner, 2008) and can be implemented by different strategies. The transactional stress model by Richard Lazarus (1999), one of the most influential frameworks on the subject, states that "the way we evaluate an event determines how we react emotionally" (Lazarus, 1999, p. 87). It has been repeatedly shown that people exposed to negative situations in experimental and natural settings display a wide variety of emotional reactions depending on their appraisal of the event (Ellsworth and Scherer, 2003; Folkman and Lazarus, 1985; Siemer et al., 2007). In addition, Gross (1998) has proposed a process model that differentiates explicit regulatory strategies depending on the point in time at which they intervene in the emotion generation process. According to this model emotion processing includes paying *attention* to an emotional stimulus of the situation one encounters, *appraisals* of this situation, as well as resulting behavioral and physiological *responses*. Accordingly, at each time point in the process, emotion regulation may occur through *attentional deployment* (during attention), *cognitive change* (during appraisal), and *response modulation*. Within this framework, Distraction is conceptualized as an attentional emotion regulation

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strategy (Kalisch et al., 2006; Kanske et al., 2011). Here, selective attention is used to focus on neutral information. Alternatively, a secondary task is performed to distract attention from the emotional stimuli of the primary task. Emotion regulation via reappraisal (cognitive change) comes in different disguises. The most studied reappraisal strategy is Reinterpretation, which implies changing the meaning of a stimulus (Ochsner et al., 2002). Another reappraisal strategy is Detachment (often also referred to as distancing or self-focused reappraisal) where one is taking the perspective of an uninvolved observer in order to reduce the subjective relevance of the stimuli. It relies upon the (explicit) generation of a self-image distanced from the experienced scene and the potentially overwhelming emotions (Kalisch et al., 2005; Staudinger et al., 2009; Walter et al., 2009). Finally, one can also modify the behavioral or physiological response to an emotional stimulus, e.g. facial expressions, which is referred to as Expressive Suppression (Vrticka et al., 2011).

These strategies are not equally effective in terms of emotion regulation success. A meta-analysis by Webb et al. (2012), including 190 studies showed that suppressing the expression of the emotional response had a small-to-medium-sized effect on emotional measures ($d_+ = 0.32$), whereas reappraising the emotional stimulus (Reinterpretation) and Detachment were more successful, with Detachment ($d_+ = 0.45$) being significantly more advantageous than Reinterpretation ($d_+ = 0.36$). Using Distraction to reduce one's emotional reaction to an aversive event only had a small positive effect on emotional measures ($d_+ = 0.27$). A possible explanation is that cognitive reappraisal and Detachment, as antecedent-focused strategies (relating to an early time point in a given emotion-generative cycle), are most effective because the emotional response has not fully unfolded and they try to alter the negativity of an event itself, whereas response-focused strategies such as Expressive Suppression often fail in controlling the emotional experience since they are initiated later in the emotion-generative process (for a review see Gross, 2002).

The neural correlates of emotion regulation are generally found in interactions between a regulation network, involving prefrontal, parietal and cingulate systems that implement control and inhibition processes and regulated subcortical systems such as the amygdala or the ventral striatum that are involved in emotion generation and affective appraisal. More precisely, the ventromedial prefrontal cortex (VMPFC), dorsomedial prefrontal cortex (DMPFC), the dorsolateral prefrontal cortex (DLPFC) and ventrolateral prefrontal cortex (VLPFC), the inferior parietal cortex (IPC) and the anterior cingulate cortex (ACC) are discussed as common brain regions supporting emotion control in general (Buhle et al., 2013; Diekhof et al., 2011; Dolcos et al., 2011; McRae et al., 2010; Ochsner et al., 2012; Phillips et al., 2008).

However, reports about the differences in the neural substrates of distinct regulatory strategies have been inconsistent and highly incomplete so far. The ACC, the VLPFC and the parietal cortex may be more active during Distraction (Erk et al., 2007; Frankenstein et al., 2001; Kalisch et al., 2006; Kanske et al., 2011; Phillips et al., 2008; Valet et al., 2004). In contrast, Reinterpretation seems to rely upon DLPFC, but also on VLPFC regions, whereas Detachment recruits the DLPFC, too, but more specifically calls upon inferior parietal regions (Ochsner et al., 2012).

Detachment has been repeatedly associated with activation in dorsal anterior cingulate (dACC), dorsal and anterior portions of the medial prefrontal cortex (mPFC), more right-sided DLPFC, middle and superior frontal cortex as well as IPC, and with a reduction of amygdala activation (Erk et al., 2010a; Kalisch et al., 2005; Koenigsberg et al., 2010; Ochsner et al., 2012; Schardt et al., 2010; Walter et al., 2009). In their review, Phillips et al. (2008) showed that Expressive Suppression was associated with activity within bilateral DMPFC, right DLPFC and left VLPFC.

Only few neuroimaging studies directly compared different emotion regulation strategies. Vrticka et al. (2011) found that during emotion regulation of positive and negative scenes superior frontal gyrus and the posterior part of the middle frontal gyrus were more strongly activated by Reinterpretation as compared to Expressive Suppression. In contrast, the superior frontal sulcus and the supplementary motor area (SMA) were more active during Expressive Suppression than during Reinterpretation. Goldin et al. (2008) compared Detachment to Expressive Suppression and found that the latter produced late (after 10.5–15 s) PFC (ventromedial, ventrolateral, dorsolateral, ACC) responses, decreased negative emotion behavior and experience, but increased amygdala and insular responses. Detachment, on the other hand, produced enhanced (early) responses in dorsal and anterior medial PFC, DLPFC and VLPFC, and lateral orbitofrontal cortex (OFC). Similarly, Kanske et al. (2011) found the orbitofrontal cortex selectively activated for reappraisal (mixed Reinterpretation and Detachment) as compared to Distraction. Both strategies were successful in reducing subjective emotional state ratings and lowered activity in the bilateral amygdala. McRae et al. (2010) showed that using Reinterpretation and Distraction resulted in decreased activation in the amygdala. However, relative to Distraction, Reinterpretation led to greater increases in DMPFC, bilateral DLPFC, and VLPFC and several left-sided clusters in temporal cortex. Relative to Reinterpretation, Distraction led to greater decreases in amygdala activation and to greater increases in activation in posterior frontal cortex, right lateral PFC, and bilateral superior parietal cortex. Price et al. (2013) compared reappraisal as Reinterpretation with Distraction by a working memory task. Reinterpretation specifically activated left VLPFC, while Distraction uniquely activated left DLPFC. All regulation strategies inhibited amygdala activity.

A direct comparison of Reinterpretation and Detachment pointed to stronger activation in right VMPFC and IPC during Detachment, whereas during Reinterpretation participants showed greater activation in left and right lateral PFC including DLPFC and VLPFC, but also in precentral gyrus, temporal gyrus and supramarginal gyrus (Ochsner et al., 2004). A combined analysis of both strategies showed reduced activation in left posterior insula and left amygdala, but the authors did not report differences in activation reductions between both strategies.

In all emotion regulation strategies common control regions like the DLPFC play a central role, but, to our knowledge, no study to date has compared more than two different regulation strategies. Investigating more than two common regulatory strategies could answer several questions. To which extent do the involved control processes and their neural substrates differ between strategies? Is there a control region common to all strategies? Is there a unique control region for each strategy? Which strategy is most effective in reducing activity in emotion generating brain circuits?

Therefore, in the present functional imaging study we aimed at comparing four widely used strategies to downregulate negative emotions, which are based on the process model of emotion regulation by Gross (1998): Detachment and Reinterpretation as antecedent cognitive appraisal strategies, Distraction as an antecedent attentional deployment strategy, and Expressive Suppression as a response-focused strategy. Based on the evidence detailed above, we hypothesized the DLPFC to play a key role in all regulation strategies because of its importance for executive processes, especially for the manipulation of stimuli in working memory. In contrast, during Reinterpretation the VLPFC and the OFC might be more strongly activated, because the VLPFC is contributing to semantic memory processes and the OFC represents stimulus value (Badre and Wagner, 2007; Rolls, 2000) while the IPC is more prominently involved in Detachment and Distraction due to attentional processes (Wager et al., 2004). Additionally, because Expressive Suppression has been repeatedly shown to be less effective to regulate negative emotion in behavioral and neuroimaging studies (Goldin et al., 2008; Webb et al., 2012), we expected the use of this strategy to result only in minor amygdala reduction in contrast to all other strategies.

Material and methods

Subjects

The protocol was approved by the ethics committee of the University Hospital of the University of Bonn and is in accordance with the Code of