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Neural activation associated with the cognitive emotion regulation of sadness in healthy children

Andy C. Belden[a,*], Joan L. Luby[a], David Pagliaccio[b,c], Deanna M. Barch[a,b,c,d]

[a] Department of Psychiatry, Washington University in St. Louis, 660 S. Euclid Avenue, St. Louis, MO 63110, USA
[b] The Program in Neuroscience, Washington University in St. Louis, 660 S. Euclid Avenue, St. Louis, MO 63110, USA
[c] Department of Psychology, Washington University in St. Louis, One Brookings Drive, St. Louis, MO 63130, USA
[d] Department of Radiology, Washington University in St. Louis, 660 S. Euclid Avenue, St. Louis, MO 63110, USA

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ABSTRACT

When used effectively, cognitive reappraisal of distressing events is a highly adaptive cognitive emotion regulation (CER) strategy, with impairments in cognitive reappraisal associated with greater risk for psychopathology. Despite extensive literature examining the neural correlates of cognitive reappraisal in healthy and psychiatrically ill adults, there is a dearth of data to inform the neural bases of CER in children, a key gap in the literature necessary to map the developmental trajectory of cognitive reappraisal. In this fMRI study, psychiatrically healthy schoolchildren were instructed to use cognitive reappraisal to modulate their emotional reactions and responses of negative affect after viewing sad photos. Consistent with the adult literature, when actively engaged in reappraisal compared to passively viewing sad photos, children showed increased activation in the vlPFC, dlPFC, and dmPFC as well as in parietal and temporal lobe regions. When children used cognitive reappraisal to minimize their experience of negative affect after viewing sad stimuli they exhibited dampened amygdala responses. Results are discussed in relation to the importance of identifying and characterizing neural processes underlying adaptive CER strategies in typically developing children in order to understand how these systems go awry and relate to the risk and occurrence of affective disorders.

1. Introduction

The development and effective implementation of adaptive CER strategies (e.g., reappraisal and problem solving) are core components of mental and physical health throughout the lifespan. Failure to develop adaptive ER strategies, the inability to use them effectively, or chronic reliance on maladaptive CER strategies (e.g., rumination, suppression, catastrophizing) has been associated with negative biological, psychological, and social outcomes (Gross, 1998; Gross and John, 2003; Zlomke and Hahn, 2010). The use of maladaptive/ineffective emotion regulation strategies has been linked to impulsivity, poor social functioning, and is a core symptom in more than 50% of all DSM-IV axis I psychiatric disorders (Gross and Munoz, 1995). Thus, identifying and characterizing the neurobehavioral basis of adaptive CER strategies in typical developing children may inform whether, when and how atypical aberrations in these processes relate to the development of childhood psychopathology.

During middle childhood, children's ER skills progress from rudimentary behavioral strategies (e.g., covering ears)

* Corresponding author at: Washington University School of Medicine, Department of Psychiatry, Box 8134, 660 S. Euclid, St. Louis, MO 63110, USA. Tel.: +1 314 286 2730; fax: +1 314 286 2732.
E-mail address: beldena@psychiatry.wustl.edu (A.C. Belden).

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to more sophisticated cognitive-based ER strategies, such as reappraisal, the cognitive re-interpretation of emotion eliciting events (Davis and Levine, 2013; Dennis and Hajcak, 2009; Garnefski et al., 2007; McRae et al., 2008). Historically, the developmental ER literature has emphasized the examination of behavioral forms of ER in children up to age 6 and cognitive forms of ER from early adolescence to adulthood. This has left a critical gap in the ER literature with fewer studies examining CER during middle childhood (ages 7–12), a critical developmental period for children's transition from behavioral to cognitive strategies for regulating emotions (Legerstee et al., 2010). The developmental period immediately preceding adolescence is especially important in relation to the study of CER for several reasons. First, the CER strategies that are developed and used with increasing frequency during adolescence are predictive of the strategies used throughout adulthood (Garnefski and Kraaij, 2006). Thus, establishing good strategies during the earliest possible developmental period may have important protective effects and could reduce the risk of adult onset psychopathology (Luby and Belden, 2006). Second, it is well established that starting in adolescence (and in relation to the commencement of puberty) the risk for the onset of psychopathology increases significantly for all children, with the risk of affective disorders rising exponentially for adolescent girls (Costello et al., 2011). Third, brain regions that support children's affective interpretation/appraisals are thought to complete structural maturation around puberty. Interestingly, puberty also marks the start of substantial structural and functional changes in brain regions known to support social cognition, emotion, and cognitive control (Luna et al., 2010). Taken together these factors suggest that understanding the neural bases for CER immediately preceding children's entry into puberty, the "storm and stress" period of development, may provide invaluable insight into how typical trajectories of ER may go awry and increase risk for mental illness (Siener and Kerns, 2012).

One CER strategy that has received the bulk of empirical focus is cognitive reappraisal (Buhle, 2013; Ochsner et al., 2012). By reinterpreting the affective meaning of emotion-eliciting situations, one may regulate and modify their emotional responses to a distressing event. Reappraisal has been consistently found to minimize the mental and/or physical toll associated with the experience of negative emotions and stressful life events (Gross, 1999, 2002; Gross and John, 2003; Gross and Munoz, 1995; Gross and Thompson, 2007). Cognitive reappraisal is an ideal starting point for examining the neural bases of emotion regulation in children. That is, cognitive reappraisal has been studied extensively in healthy and psychiatrically ill adults, has clinical value (e.g., often taught in Cognitive Behavioral Therapy), and is feasible to teach and implement in neuroimaging settings with younger samples.

While the literature suggests that children as young as 5 show the ability for cognitive ER (DeCicco et al., 2012), there are very few studies that have used fMRI to examine the neural substrates associated with the cognitive reappraisal of sadness in children prior to age 13 (Levesque et al., 2003). This is an especially important area of study given that once children have the cognitive and neurobiological processes in place to support cognitive reappraisal (with varying degrees of effectiveness), it is likely that they will rely on this ER strategy with increasing frequency as they age (Garnefski et al., 2002b). Furthermore, fMRI studies of reappraisal in children and adults have emphasized the down-regulation of highly arousing negative emotions such as disgust and fear. Although sadness is low in arousal compared to disgust or fear it was the focus of the current study for one primary reason. That is, sadness has a prevailing role in the occurrence and course of childhood onset depression. Our overarching future goal is to compare neural activation in healthy compared to depressed children using this same reappraisal of sadness task. Based on this, we focused our study on the CER of sadness.

1.1. Neural substrates of cognitive reappraisal in adulthood

Cognitive reappraisal is well characterized and commonly used in adults (Ochsner and Gross, 2007; Ochsner et al., 2012) where it has been linked to neural activation in two distinct, but anatomically connected, brain systems (Gross and Thompson, 2007; Ochsner et al., 2001; Phillips et al., 2008). One system of particular interest for the current study includes emotional reaction/processing/generation regions including the amygdala, ventral striatum, ventromedial PFC, the insula, and others. Although an oversimplification of the complexity of the neural circuitry of emotion processing, these regions are often referred to as a "ventral" system implicated in "bottom-up" generation of emotion (Ochsner et al., 2001; Ochsner and Gross, 2003, 2005, 2007, 2008; Ochsner and Phelps, 2007). The amygdala is implicated in the perception, labeling, and encoding of stimuli with a particular sensitivity to threat and fear (Cunningham et al., 2008; Kim et al., 2010b; Neta and Whalen, 2011). The ventral striatum is thought to be involved in determining which cues from the environment predict rewarding or reinforcing outcomes (Van Leijenhorst et al., 2010). Affective appraisals of stimuli processed in the amygdala and ventral striatum, along with input from other regions (e.g., medial temporal lobules), are integrated within the ventromedial prefrontal cortex (vmPFC). The vmPFC tracks the positive or negative appraisal of stimuli in a goal-dependent manner (Ochsner et al., 2012). Similar to the amygdala and ventral striatum, the insula is another region implicated in emotion reactivity/processing of emotionally distressing experiences (Eugene et al., 2003; Johnstone et al., 2007).

The second neural system utilized for cognitive reappraisal involves PFC and cingulate regions and is thought to support "top-down" control processes, which modulate activity in posterior and subcortical systems that generate emotional responses (Ochsner et al., 2002). The dorsolateral prefrontal cortex (dlPFC) and posterior portions of the PFC, in conjunction with inferior parietal regions, are implicated in attending to reappraisal-relevant stimulus features and maintaining awareness of reappraisal goals (Wager and Smith, 2003). Dorsal regions of the anterior cingulate cortex (ACC) are implicated in performance monitoring and are thought to help organize the extent to which