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Neural correlates of cognitive reappraisal in children: An ERP study

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ABSTRACT

Cognitive emotion regulation strategies, such as reappraising the emotional meaning of events, are linked to positive adjustment and are disrupted in individuals showing emotional distress, like anxiety. The late positive potential (LPP) is sensitive to reappraisal: LPP amplitudes are reduced when unpleasant pictures are reappraised in a positive light, suggesting regulation of negative emotion. However, only one study has examined reappraisal in children using the LPP. The present study examined whether directed reappraisals reduce the LPP in a group of 5- to 7-year-olds, and correlate with individual differences in fear and anxiety. EEG was recorded from 32 typically developing children via 64 scalp electrodes during a directed reappraisal task. Mothers reported on child anxiety. Fearful behavior was observed. As predicted, LPP amplitudes were larger to unpleasant versus neutral pictures; counter to predictions, the LPP was not sensitive to reappraisal. The degree to which unpleasant versus neutral pictures elicited larger LPPs was correlated with greater anxiety and fear. Results suggest that reappraisal in young children is still developing, but that the LPP is sensitive to individual differences related to fear and anxiety. The utility of the LPP as a measure of cognitive emotion regulation and emotional processing biases in children is discussed.

1. Introduction

Emotion regulation involves the ability to change our experience of and attention to emotional information (Gross and Thompson, 2007). The study of emotion regulation in adults often focuses on the use of cognitive emotion regulation strategies (e.g., Moser et al., 2006, 2009; Hajcak et al., 2009; Hajcak and Nieuwenhuis, 2006; Krompinger et al., 2008). One such strategy, reappraisal, serves to change the emotional meaning and significance of an event or stimulus (Foti and Hajcak, 2008; Gross and John, 2003; Hajcak and Nieuwenhuis, 2006; Kalisch et al., 2006; Ochsner et al., 2002; Ochsner and Gross, 2005). For example, when viewing a picture of a man who is lying in a hospital bed, one could reappraise this picture in a more positive light by describing the man as a person who was sick, but is now on his way to making a full recovery. Difficulty in the ability to use reappraisal to modify the significance and meaning of unpleasant emotional material has been linked to problems with adjustment, such as mood disruptions (e.g., Gross and John, 2003). Other emotion regulation strategies, such as suppression, appear to be inferior to reappraisal because they are response-focused and thus occur *after* an emotional reaction has already occurred (Gross, 1998). Indeed, suppression compared to reappraisal is associated with increased cognitive and physiological "load", impaired memory, and poorer adjustment (Gross and John, 2003; Richards and Gross, 2000; Gross and Levenson, 1993, 1997).

Neuroscience studies with adults have identified neural mechanisms supporting the ability to reappraise. While reappraising, adults show increased activity in areas of

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the prefrontal cortex (PFC), including the dorsal lateral prefrontal cortex and dorsal anterior cingulate cortex; in contrast, subcortical regions associated with emotional arousal and emotional processing such as the amygdala are less active (Ochsner et al., 2002; Phan et al., 2005; Urry et al., 2006). This suggests that prefrontally mediated cognitive control resources are being recruited to down-regulate the experience of negative emotion. To date, the single fMRI study examining reappraisal in children (aged 5-10) shows similar patterns: when asked to reappraise sad stimuli, portions of the lateral and medial PFC were bilaterally activated in addition to the right ACC and right ventral lateral PFC activation (Levesque et al., 2004). These neuroimaging studies identify neural regions involved in emotion regulation with excellent spatial resolution; however, key emotion regulation processes may occur on the order of milliseconds and thus emerge more rapidly than can be detected via fMRI. Scalp-recorded event related potentials (ERPs) have excellent temporal resolution on the order of milliseconds, and thus are capable of capturing such rapid changes resulting from the use of cognitive emotion regulation strategies.

One ERP that is particularly well-suited for examining reappraisal is the late positive potential (LPP). The LPP emerges around 200-300 ms following stimulus onset and tends to be maximal at centro-parietal recording sites (e.g., Cuthbert et al., 2000; Foti and Hajcak, 2008; Hajcak and Nieuwenhuis, 2006). The LPP reflects increased processing of and facilitated attention to emotional stimuli, such that LPP amplitudes are larger to emotional versus neutral stimuli like pictures, faces, and words (Cuthbert et al., 2000; Schupp et al., 2000, 2004; Herbert et al., 2008). Several studies have shown that the LPP is sensitive to emotion regulation strategies such as directed reappraisal (Foti and Hajcak, 2008; MacNamara et al., 2011) and directions to increase and decrease subjective emotional responses (Hajcak and Nieuwenhuis, 2006; Moser et al., 2006, 2009; Krompinger et al., 2008). Specifically, LPP amplitudes are reduced when adults are asked to reappraise an unpleasant stimulus in a more positive light compared to a negative appraisal (Foti and Hajcak, 2008), or when instructed to use cognitive strategies to decrease versus increase subjective emotional responses to pleasant (Krompinger et al., 2008) and unpleasant stimuli (e.g., Moser et al., 2006, 2009; Hajcak and Nieuwenhuis, 2006). These changes in the LPP, in adults, are correlated with reduced subjective arousal (Hajcak and Nieuwenhuis, 2006), suggesting the effective down-regulation of emotion, and are independent of factors that might increase cognitive load, such as task difficulty (Hajcak et al., 2006). A recent study also examined the LPP 30 min after a directed reappraisal task and found that LPP amplitudes were larger to reappraised stimuli versus those that were not reappraised (MacNamara et al., 2011). Therefore, the LPP is sensitive to changes in emotional processing that result from the use of cognitive emotion regulation strategies like reappraisal.

To date, however, only two published studies have examined the LPP in response to complex emotional pictures in children (Dennis and Hajcak, 2009; Hajcak and Dennis, 2009) and one study examined an LPP-like ERP component, the P400, in children, in response to emotional faces (Leppanen et al., 2007). In research from our lab, we confirmed that the LPP is sensitive to emotional stimuli in children: LPP amplitudes were larger to pleasant and unpleasant as compared to neutral stimuli in 5- to 10-year-old children (Hajcak and Dennis, 2009). In the other study (Dennis and Hajcak, 2009), we demonstrated that 5- to 10-year-old children were able to use directed reappraisal strategies to modulate the LPP, similar to effects found in adults: LPP amplitudes were reduced to unpleasant stimuli when reappraisal versus negative stories were provided. However, effects of reappraisal strategy emerged around 600–1000 ms, which is later than the timing documented in studies with adults (Foti and Hajcak, 2008; MacNamara et al., 2009). Moreover, reappraisal was *not* effective in modulating the LPP in younger girls in the sample (ages 5–6). In fact, younger girls in this study showed the opposite effect such that LPP amplitudes were larger that were reappraised versus those with negative stories. For the sample as a whole, LPP amplitudes were reduced in the reappraisal versus negative story condition (indicating effective down-regulation of the LPP via reappraisal) and were associated with fewer anxious/depressed symptoms while reappraisals (of unpleasant stimuli) were associated with more symptoms.

This first study (Dennis and Hajcak, 2009) examining reappraisal and the LPP in children therefore suggests that children are able to effectively use reappraisal to modulate how they process unpleasant emotional stimuli as measured via the LPP, that effects may vary by age and gender, and that these changes in the LPP correlate with individual differences in mood and anxiety. Several methodological issues in the Dennis and Hajcak (2009) study, however, limited our ability to fully interpret results. For example, this previous study included a somewhat small sample size ($N = 20$) and lacked a neutral baseline condition. Additionally, the methodological parameters of Dennis and Hajcak (2009) were meant to bolster young children's ability to reappraise, a method that differs from the adult literature on reappraisal: reappraisal stories *followed* presentation of emotional pictures, whereas in the adult literature reappraisals always precede emotional stimuli given that reappraisal is conceptualized as an antecedent-focused strategy that occurs prior to an emotional reaction.

Thus, the goal of the present study was to add to the literature on reappraisal and the LPP in children and to clarify findings from Dennis and Hajcak (2009) by increasing the sample size, designing the reappraisal paradigm to mirror paradigms used in the adult literature, and focusing on younger age range of study (around ages 5–6) in which effects of reappraisal were unclear. This age period, when children are in kindergarten or first grade is a particularly important period in the development of cognitive emotion regulation. First, factors such as ongoing brain maturation, exposure to peers, and participation in structured education support more sophisticated cognitive and emotional abilities (Thompson and Goodman, 2010). Moreover, more complex information processing skills allow children at this age to generate emotion regulation strategies in more creative and independent ways (Garber et al., 1991; Gross and Thompson, 2007). The literature on the