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PAPER

# The late positive potential predicts emotion regulation strategy use in school-aged children concurrently and two years later

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## Abstract

*The ability to use cognitive emotion regulation strategies such as reappraisal may be a core component of emotional competence across development, but due to methodological challenges in measuring such strategies, they are rarely studied in young children. One neurophysiological measure, the late positive potential (LPP), has been examined in response to reappraisal as a potential neurosignature for emotion regulatory capacity in adults. The association between the LPP and emotion regulatory capacity in children is unknown. The present study examined whether the LPP during reappraisal could predict greater observed adaptive emotion regulation strategy use in school-aged children over a two-year period. Thirty-two 5- to 7-year-olds participated in two identical lab visits spaced two years apart. EEG was continuously recorded during a computerized reappraisal task in which children viewed unpleasant images paired with either reappraisal or negative stories. Next they completed a disappointing and a frustrating task during which emotion regulation strategies were observed. As predicted, children who showed reappraisal-induced reductions in the LPP at the first assessment used significantly more adaptive ER strategies concurrently and two years later. These findings provide observation-based evidence that the LPP may be a viable neurosignature for emotion regulatory capacity in children.*

## Research highlights

- The use of cognitive emotion regulation strategies such as reappraisal may reflect a core aspect of emotional competence, but is rarely studied in children.
- The late positive potential (LPP) during reappraisal was examined in relation to observed emotion regulatory strategies in school-aged children.
- Children who showed reappraisal-induced reductions in the LPP at the first assessment used significantly more adaptive emotion regulation strategies concurrently and two years later.
- These findings provide observation-based evidence that the LPP may be a viable neurosignature of emotion regulatory capacity in children.

## Introduction

Emotion regulation (ER) is the ability to monitor, evaluate, and modify emotional reactions to accomplish goals (Gross & Thompson, 2007). One cognitive strategy, reappraisal, involves the ability to change the emotional meaning and significance of a stimulus (Foti & Hajcak, 2008; Gross & John, 2003; Ochsner & Gross, 2005). For example, the image of a man with a cast may evoke negative emotions, but the reappraisal that his wound was treated and he will likely recover can serve to reduce these emotions. The ability to use reappraisal is associated with positive adjustment in adults, and difficulties in reappraisal have been linked to poor mental health outcomes (Gross & John, 2003; Moore, Zoellner & Mollenholt, 2008). Thus, the ability to use cognitive ER

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strategies like reappraisal may be a core component of emotion regulatory competence (Cole, Martin & Dennis, 2004; Dennis & Kelemen, 2009; Kopp, 1989). However, due to its cognitive nature and the involvement of higher-order abilities (i.e. verbal mediation, perspective taking), reappraisal is difficult to measure without self-report and thus has received relatively little attention in the child development literature (Cole *et al.*, 2004).

Emerging evidence indicates that a scalp-recorded event-related potential (ERP) called the late positive potential (LPP) is sensitive to reappraisal (Foti & Hajcak, 2008; Hajcak & Nieuwenhuis, 2006; MacNamara, Ochsner & Hajcak, 2011). This slow, positive-going waveform emerges around 200 to 300 ms after the presentation of emotional visual stimuli and is maximal at parietal recording sites in adults and occipital sites in children (Hajcak & Dennis, 2009; Kujawa, Klein & Hajcak, 2012b). LPP amplitudes are reliably larger to emotional versus neutral stimuli and thus are thought to reflect facilitated attention to and processing of emotional stimuli (Cuthbert, Schupp, Bradley, Birbaumer & Lang, 2000; Hajcak & Nieuwenhuis, 2006). Given this characteristic, several researchers have shown that when adults are instructed to reappraise an unpleasant image in a more neutral or positive way, LPP amplitudes are reduced (e.g. Foti & Hajcak, 2008; MacNamara *et al.*, 2011). Furthermore, the degree to which the LPP is changed during reappraisal is correlated with the subjective emotional arousal of participants (e.g. Hajcak & Nieuwenhuis, 2006). In this way, modulation of the LPP may represent an index of regulatory capacity.

Yet, it remains unclear whether the LPP is sensitive to reappraisal in young children. For example, while one study (Dennis & Hajcak, 2009) showed that, overall, 5- to 10-year-olds showed adult-like reductions in LPP amplitudes to unpleasant stimuli following directions to reappraise, this was not the case for the younger end of the age range, who showed *increased* LPP amplitudes to the reappraisal condition. In another study targeting 5- to 7-year-olds, children failed to show adult-like reductions in the LPP to unpleasant stimuli in a reappraisal versus negative story condition (DeCicco, Solomon & Dennis, 2012), although this same group of children showed the expected reappraisal-induced reductions in the LPP by 8 to 9 years (DeCicco, O'Toole & Dennis, in press).

If this modulation of the LPP reflects regulatory capacity, then it should predict the ability to use adaptive ER strategies. While several studies have shown that changes in the LPP are associated with questionnaire-based measures of mood problems (DeCicco *et al.*, 2012; MacNamara & Hajcak, 2009), no research documents links between the LPP and observed ER strategy use. The present study pursued this gap in the research by examining whether the LPP in response to reappraisal is concurrently and longitudinally associated with school-aged children's use of observed ER strategies.

Several ER strategies in childhood may be adaptive across a wide range of situations and individuals (Bonanno & Burton, 2013; Cole, Michel & Teti, 1994), such as those that intentionally shift attention away from emotionally distressing situations to regulate arousal (Eigsti, Zayas & Mischel, 2006; Mischel, Ebbesen & Raskoff Zeiss, 1972), use of parents to bolster regulatory attempts, and use of alternative activities and reorienting behaviors to weather emotional challenges (Calkins & Johnson, 1998; Grolnick, Bridges & Connell, 1996; Kopp, 1982). Reorienting away from an emotional challenge and engaging in an alternative activity may be particularly adaptive and developmentally sophisticated because this requires significant inhibitory and executive control, perhaps more than that recruited during the passive use of attentional distraction or gaze aversion. Alternatively, use of a range of alternative activities may reflect a child's ability to flexibly switch cognitive approaches to regulate the intensity of engagement with the emotional challenge (Cole *et al.*, 2004; Zimmermann & Stansbury, 2003). Indeed, Kashdan and Rottenberg (2010) define psychological flexibility as how a person '(1) adapts to fluctuating situational demands, (2) reconfigures mental resources, (3) shifts perspective, and (4) balances competing desires, needs, and life domains' (p. 866).

If the LPP is a neurocognitive measure of regulatory capacity, it should vary systematically with the use of adaptive ER strategies. The present study was a preliminary examination of this novel question which used a subsample from a previous study (DeCicco *et al.*, 2012). We tested the hypothesis that reappraisal-induced reductions in the LPP in 5- to 7-year-olds will concurrently and longitudinally (two years later) predict greater use of spontaneously generated adaptive ER strategies (e.g. distraction, social engagement, alternative activities) during two emotional challenges.

## Method

### *Participants*

Participants during the first visit (T1) were 32 typically developing children (11 female), aged 5 to 7 years ($M$ = 76.0 months, $SD$ = 6.48). At T1, 10 (31.3%) participants were White, 13 (40.6%) were Black/African-American, 4 (12.5%) were Hispanic/Latino, 2 (6.3%)

were Asian, 2 (6.3%) were both Hispanic and another category, and 1 (3.1%) selected other. Of these 32 children, 21 (7 female), aged 7 to 9 years ($M$ = 98.6 months, $SD$ = 7.55) returned for a second (T2) visit two years later. At T2, 4 (19.0%) participants were White, 10 (47.6%) were Black/African-American, 4 (19.0%) were Hispanic/Latino, 2 (9.5%) were both Hispanic and another category, and 1 (4.8%) selected other. Participants for the present study were a subsample from a previous study ($N$ = 32) testing whether the LPP was sensitive to reappraisal in 5- to 7-year-olds (DeCicco *et al.*, 2012).

### *Procedure*

Children and caregivers visited the lab twice for identical sessions lasting approximately three hours each. Following informed consent and assent procedures, children were fitted with a nylon cap into which electrodes were inserted. Electroencephalography (EEG) setup took place while children watched cartoons. Stimuli were displayed in color using Presentation software (Version 2, Neurobehavioral Systems, Inc., Albany, CA), and occupied the entire screen of an IBM computer (17″ monitor). Children sat 65 cm away from the monitor. Subsequently, participants completed behavioral tasks, which were video recorded to allow for observation of ER strategies. Parents were compensated with $100.00 and children were given a certificate of completion and astronaut ice cream.

### Emotion regulation tasks

*Waiting task (WT) .* The purpose of the WT was to elicit distress by asking children to wait to open an attractively wrapped gift until their parent completed questionnaires in the same room (Cole, Teti & Zahn-Waxler, 2003; Vaughn, Kopp & Krakow, 1984). Before the task, the researcher gave the parent paperwork to complete, placed the gift on the table and gave the child a boring toy (small plastic fish). Parents were instructed tell their children: ‘This is a surprise for you, but you must to wait until I finish my work to open it.’ The goal of this task was for children to inhibit themselves from opening the present while parents were busy. Parents were free to interact with their children as they wished. This task lasted 10 minutes.

*Disappointment task (DT) .* This task was adapted from one used by Cole, Zahn-Waxler and Smith (1994). A researcher asked the child to choose one toy from an array of five desirable toys and one undesirable toy (T1: baby toy, T2: broken sunglasses). The child was told that the chosen toy would be delivered to him/her shortly by another (unfamiliar) researcher. After the child made his/her choice, the researcher took all the toys and left the room. After one minute, the unfamiliar researcher entered, placed the undesirable toy on the table in front of the child, and left. After another minute, the original researcher returned and sat next to the child. The researcher did not initiate conversation for 30 seconds. If the child spoke during this time, the researcher responded by neutrally paraphrasing the child. The researcher then asked, ‘Do you like that toy?’ After another 30 seconds, the researcher admitted that the wrong toy was delivered, and retrieved the correct toy. The goal of this task was for children to effectively cope with disappointment.

### Behavioral coding and data aggregation

ER behaviors were observed on video and scored by two reliable raters (κ = .66–1.0). A total of eight strategies were coded in both tasks including: self-comforting, prohibited object engagement, social engagement, distraction, alternative activities, instrumental behaviors, object engagement, and passive withdrawal. Behavioral strategy ratio scores were calculated for each task by dividing the frequency of each strategy by the total number of behaviors performed during that task. A denominator of total regulatory behaviors exhibited, whether potentially adaptive or maladaptive, was used to control for individual differences in activity level. For each task, only those ratio scores for behaviors which were observed in at least 90% of children during the task at both T1 and T2 were included in analyses. Each ratio score represents the frequency with which a child used a strategy compared to all other regulatory behaviors used during that task.

For the DT, analyzed behaviors include: distraction, alternative activities, and object engagement. For the WT, analyzed behaviors include: social engagement, prohibited item engagement, alternative activities, and object engagement (see Appendix). The literature suggests that these strategies are adaptive across individuals and contexts, with the exception of prohibited item engagement perhaps reflecting difficulty complying with the rules of the task (Grolnick *et al.*, 1996; Kopp, 1982; Mischel *et al.*, 1972).

### Cognitive reappraisal task

Children completed the cognitive reappraisal task while EEG was recorded continuously. Immediately preceding the task, the following verbal instructions were given to children:

For our next game we're going to see some pictures. Listen to the stories and think of the pictures so that they match the stories. Remember to stay still and look at the screen. Try to match the story to the picture. If you need to tell me anything, wait until the game is over to tell me.

In this task, 45 developmentally appropriate pictures were taken from the International Affective Picture System (IAPS; 30 unpleasant and 15 neutral).[1] Half of the unpleasant stimuli were preceded by a negative story, and half were preceded by a reappraisal story (Dennis & Hajcak, 2009), with the type of story presented first counterbalanced across participants. Neutral pictures were paired with neutral stories. In total, there were three conditions: unpleasant pictures preceded by a negative story, unpleasant pictures preceded by a reappraisal story, and neutral pictures preceded by a neutral story. After hearing each story, there was a 500 ms delay prior to stimulus onset. Stimuli were then presented for 2000 ms with a 1500 ms inter-trial interval between each stimulus and the next story. After the first block of unpleasant pictures preceded by negative or reappraisal stories (30 trials), participants took a break and then completed a second block (30 trials). Children then completed two neutral blocks (15 trials each) which were used as a baseline condition. The second unpleasant and neutral blocks used the same stimulus/story pairings as their respective first blocks to allow for the greatest number of trials. A video camera was in the booth and was monitored by a researcher outside to ensure that children were completing the task.

### *EEG recording and data reduction*

During the reappraisal task, EEG activity was continuously recorded via 64 Ag/AgCl scalp electrodes sampled at 512 Hz (BioSemi, Amsterdam, NL). Electrodes were fixed into an elasticized nylon cap and arranged according to the international 10/20 system. Eye movements were measured by electro-oculogram (EOG) signals from electrodes positioned 1 cm above and below the left eye (to monitor vertical eye movements) and 1 cm from the outer edge of each eye (to monitor horizontal eye movements). Pre-amplification of the EEG signal occurred at each electrode which improves the signal-to-noise ratio. The voltage from each of the 64 electrodes from which data were collected was referenced online with respect to the common mode sense active electrode, which produces a monopolar (nondifferential) channel. Brain Vision Analyzer (Version 2.2, GmbH, Munich, DE) was used to prepare the data. Offline, all data were re-referenced to the mastoids and filtered with a low cut-off frequency of .1 Hz and a high cut-off frequency of 30 Hz. Stimulus-locked data were segmented into epochs ranging from 400 ms before stimulus presentation to 2000 ms after, with a 400 ms baseline correction.

Independent components analysis was used to correct for blinks. Artifacts were identified using the following criteria and removed from analyses: data with voltage steps greater than 75 µV, changes within a given segment greater than 200 µV, amplitude differences greater than ± 120 µV in a segment, and activity lower than .2 µV per 100 ms. In addition to this semi-automatic identification of artifacts, trials were also visually inspected for further artifacts which were removed on a trial-by-trial-basis.

The LPP was generated between 300 ms and 800 ms, the period of maximal deflection, across electrodes O1, O2, Oz, PO3, PO4, PO7, PO8, and POz. These electrodes were chosen via visual inspection of topographical distributions and are consistent with research with children showing maximal LPP amplitudes at occipital recording sites (Kujawa, Hajcak, Torpey, Kim & Klein, 2012a; Kujawa, Weinberg, Hajcak & Klein, 2012c).

To quantify the degree to which reappraisal resulted in reduced LPP amplitudes, difference scores were computed by subtracting LPP amplitudes for reappraisal stories from LPP amplitudes for negative stories (LPP negative story − LPP reappraisal story). Positive scores indicate that LPP amplitudes are lower following reappraisal compared to negative stories.

## Results

### *Descriptive statistics*

Descriptive statistics for observed ER strategies are presented in Table 1 and grand-average waveforms for LPPs for the reappraisal, negative, and neutral story conditions are presented in Figure 1a.

Correlations were conducted to determine whether ER strategy use and LPP measures of reappraisal varied with age at T1. Older children used distraction less frequently in the DT [$r(32) = -.489$, $p < .01$], suggesting an age shift in the use of this attention-based strategy. In addition, an independent-samples *t*-test determined that during T1, females ($M = .32$, $SD = .14$) used distraction during the DT significantly more than males ($M = .21$, $SD = .12$),

[1] Previous studies e.g. Hajcak & Dennis, 2009) demonstrated that children in this age range could not successfully subjectively rate stimuli, so arousal and valence ratings were not obtained from participants. Stimuli were previously rated for valence and arousal by adults, and these ratings corresponded to expected pleasant, neutral, and unpleasant images (Lang, Bradley & Cuthbert, 2008).

**Table 1** *Behavioral descriptive statistics*

| Task | Time | Behavior | *N* | *M* (*SD*) | Range |
|---|---|---|---|---|---|
| Disappointment | T1 | Distraction | 32 | 0.25 (0.14) | 0.00–0.67 |
| | | Alternative Activities | | 0.25 (0.13) | 0.00–0.54 |
| | | Object Engagement | | 0.26 (0.17) | 0.04–0.91 |
| | T2 | Distraction | 21 | 0.21 (0.13) | 0.00–0.47 |
| | | Alternative Activities | | 0.19 (0.11) | 0.00–0.47 |
| | | Object Engagement | | 0.31 (0.10) | 0.13–0.44 |
| Waiting | T1 | Prohibited Object | 32 | 0.15 (0.09) | 0.00–0.30 |
| | | Social Engagement | | 0.11 (0.10) | 0.00–0.46 |
| | | Alternative Activities | | 0.33 (0.10) | 0.15–0.51 |
| | | Object Engagement | | 0.21 (0.10) | 0.06–0.53 |
| | T2 | Prohibited Object | 21 | 0.10 (0.06) | 0.02–0.19 |
| | | Social Engagement | | 0.09 (0.06) | 0.00–0.22 |
| | | Alternative Activities | | 0.35 (0.11) | 0.21–0.59 |
| | | Object Engagement | | 0.26 (0.10) | 0.11–0.53 |

$t(30) = 2.347$, $p < .05$. To account for these and other potential gender differences and age shifts in strategy preference, gender and age in months were used as covariates in subsequent analyses.

## Relations among ER strategies

Correlations were conducted for strategies observed during the DT (Table 2) and the WT (Table 3) separately. These correlations suggest that children who used alternative activities and distraction spent less time engaging with the prohibited and boring objects. Also, alternative activity use was associated with less social engagement in the form of talking to the parent about the task during the WT.

### *Effects of reappraisal on the LPP*

Since the current study uses a subsample from a previous study (DeCicco *et al*., 2012), we first confirmed that, like the findings from the full sample, LPP amplitudes were not significantly reduced in the reappraisal versus negative condition overall. We conducted a 3 (Condition: reappraisal story, negative story, neutral story) × 2 (Gender) repeated measure ANOVA with age in months as a covariate. No significant main effect emerged for condition [$F(2, 58) = .361$, $p > .05$].

Although for the sample as a whole, the effect of reappraisal on LPP amplitudes did not reach significance, children at T1 showed great variability in whether or not LPPs were reduced during the reappraisal versus negative story condition. Positive LPP difference scores indicated that LPPs were smaller to reappraisal stories compared to negative stories, whereas negative LPP difference scores indicated the opposite. Therefore, we examined whether children were distinguishable in terms of whether they showed positive or negative difference scores, with only the former indicating reduction of LPPs via reappraisal. We divided the sample into two statistically different groups, with those with positive reappraisal scores ($n = 14$) having significantly greater scores ($M = 3.95$, $SD = 2.74$) compared to those with negative reappraisal scores ($n = 18$; $M = -4.60$, $SD = 4.15$), $t(30) = -6.642$, $p < .001$. Splitting the sample at a difference score of zero represents a meaningful distinction among children, as opposed to a median split. As depicted in Figure 1b, the positive reappraisal score group showed smaller LPP amplitudes following the reappraisal versus negative story condition, whereas the inverse was true for the negative reappraisal score group.

### *Associations between the LPP and observed ER*

To test our primary hypothesis that children showing reduced LPPs via reappraisal would use more adaptive observed ER strategies, we took two analytic approaches. First, we conducted correlations between LPP reappraisal differences scores at T1 and observed ER strategies at T1 and T2, with age in months as a covariate.

Next, we conducted a series of analyses of covariance (ANCOVA) in which reappraisal group (positive reappraisal scores versus negative reappraisal scores) was the between-subjects variable. ER strategies (prohibited object engagement, social engagement, distraction, alternative activities, and object engagement) were examined in separate models, with ANCOVAs for each strategy conducted separately for each task (WT and DT), and for concurrent and longitudinal analyses. To predict ER strategy use at T1 from LPP reappraisal at T1, age in months and gender were covariates, and T1 ER strategy ratio score was the outcome variable. To predict ER strategy use at T2 from LPP reappraisal at T1, T1 LPP reappraisal group was the between-subjects variable, age in months, gender, and T1 ER strategy ratio score were covariates, and T2 ER strategy ratio score was the outcome variable, separately for each strategy.[2] T1 ER

[2] Effects remained the same when non-parametric tests were used.

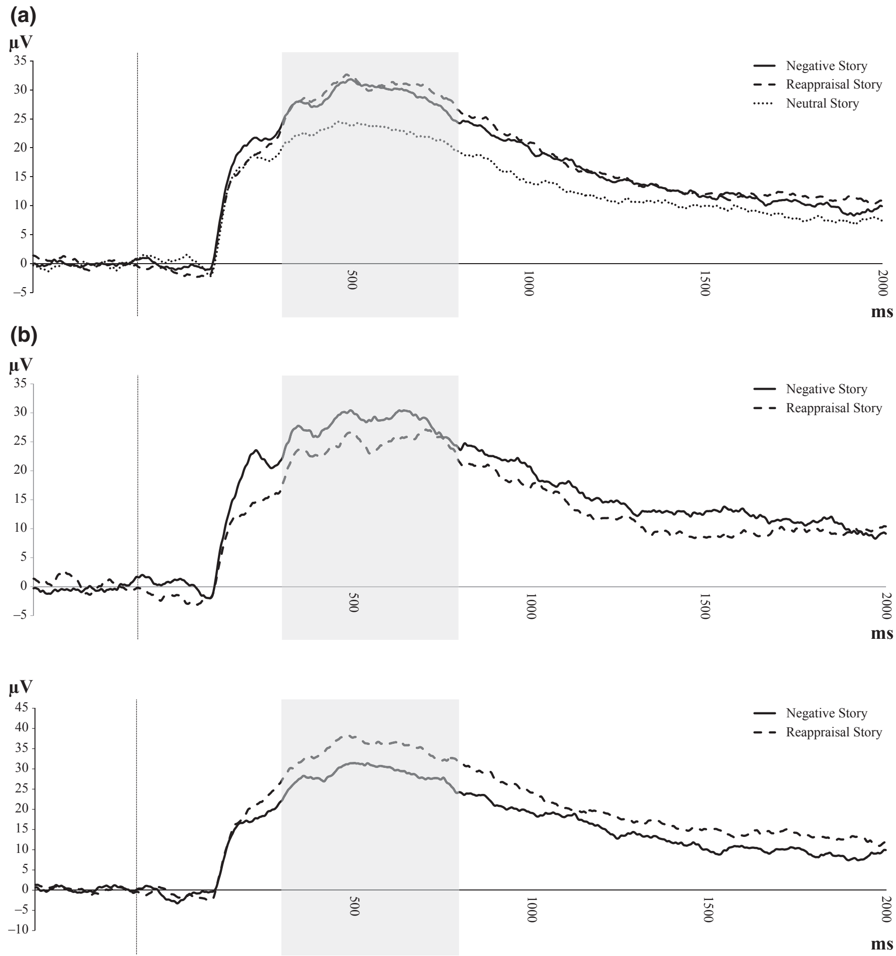


**Figure 1** *(a) Grand average LPP waveforms for the reappraisal, negative story, and neutral story conditions. (b) LPP waveforms for children who showed a positive reappraisal score (above) and negative reappraisal score (below) at T1.*

strategy frequency was included as a covariate in these longitudinal ANCOVAs to determine whether or not T1 LPP predicts T2 ER when individual differences in T1 ER are taken into account.

### *Correlations between LPP at T1 and observed ER strategies*

As predicted, greater LPP difference scores, indicating a greater effect of reappraisal, were associated with increased alternative activity use in the WT at T1 [$r(18) = .60$, $p < .01$] and in the DT at T2 [$r(18) = .52$, $p < .05$]. No other significant correlations emerged.

### *T1 LPP reappraisal grouping predicting T1 ER behavior*

#### Disappointment task

No significant effects emerged.

#### Waiting task

As predicted, children showing a positive reappraisal score versus those showing a negative reappraisal score used alternative activities more frequently, $F(1, 28) = 10.366$, $p < .01$, $M$ ($SE$) = .38(.02) vs .28 (.02) (Figure 2).

### *T1 LPP reappraisal grouping predicting T2 ER behavior*

#### Disappointment task

As predicted, children showing a positive reappraisal score versus those showing a negative reappraisal score used alternative activities more frequently at T2, $F(1, 16) = 8.002$, $p < .05$, $M$ ($SE$) = .27 (.03) vs. .15 (.03) (Figure 2).

#### Waiting task

No significant effects emerged.

**Table 2** *Correlations among emotion regulation strategies during the disappointment task*

| | Time 1 | | | Time 2 | | |
|---|---|---|---|---|---|---|
| | OE | D | AA | OE | D | AA |
| Time 1 ($N$ = 32) | | | | | | |
| OE | 1 | −.40* | −.38* | −.17 | .11 | .05 |
| D | −.40* | 1 | −.02 | −.04 | .34 | −.00 |
| AA | −.38* | −.02 | 1 | .29 | .11 | −.06 |
| Time 2 ($N$ = 21) | | | | | | |
| OE | −.17 | −.04 | .29 | 1 | −.35 | .00 |
| D | .11 | .34 | .11 | −.35 | 1 | −.01 |
| AA | .05 | −.00 | −.06 | .00 | −.01 | 1 |

*$p$ < .05; OE = object engagement. D = distraction. AA = alternative activities.

**Table 3** *Correlations among emotion regulation strategies during the waiting task*

| | Time 1 | | | | Time 2 | | | |
|---|---|---|---|---|---|---|---|---|
| | POE | OE | AA | SE | POE | OE | AA | SE |
| Time 1 | | | | | | | | |
| POE | 1 | −.36* | −.19 | −.18 | .11 | .28 | .15 | .03 |
| OE | −.36* | 1 | −.28 | −.09 | −.24 | .14 | −.41^ | .22 |
| AA | −.19 | −.28 | 1 | −.34* | .07 | −.24 | .18 | .07 |
| SE | −.18 | −.09 | −.34^ | 1 | −.13 | .11 | .03 | −.18 |
| Time 2 | | | | | | | | |
| POE | .11 | −.24 | .07 | −.13 | 1 | −.43* | .17 | .42^ |
| OE | .28 | .14 | −.24 | .11 | −.43* | 1 | −.45* | −.16 |
| AA | .15 | −.41^ | .18 | .03 | .17 | −.45* | 1 | −.33 |
| SE | .03 | .22 | .07 | −.18 | .42^ | −.16 | −.33 | 1 |

*$p$ < .05 or $p$ = .05; ^$p$ < .10, marginal. POE = prohibited object engagement. OE = object engagement. AA = alternative activities. SE = social engagement.

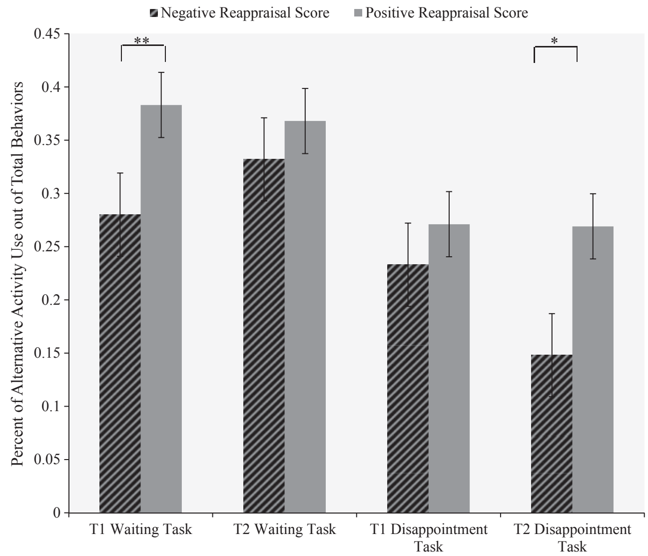


**Figure 2** *Alternative activity use in the negative reappraisal and positive reappraisal score groups (*p < .05, **p < .01; adjusted means are presented with error bars representing standard errors).*

## Discussion

These results suggest that reappraisal-induced reductions in the LPP were associated with greater use of alternative activities during emotional challenges concurrently and two years later. These associations between the LPP and ER behaviors provide, for the first time, longitudinal and behavioral evidence that the LPP may have utility as an indicator of regulatory capacity in children.

The ability to disengage from an emotionally distressing task and engage in an alternative, self-generated activity has been associated with decreased emotional distress in children (Grolnick *et al*., 1996) and may indicate meaningful individual differences in regulatory flexibility (Bonanno & Burton, 2013), attentional flexibility (Babb, Levine & Arseneault, 2010), and executive control (Carlson & Wang, 2007). In the current study, the use of several different alternative activities throughout the distressing tasks may indicate a large repertoire of available strategies and thus, regulatory flexibility. However, some children with high alternative activity ratio scores may have engaged in few alternative activities multiple times throughout the task, rather than many different activities. While being able to shift attention away from the challenge in order to engage in another activity likely indicates attentional flexibility; whether it signifies regulatory flexibility is an open question. Zimmermann and Stansbury (2003) showed that, during a distressing stranger paradigm, children with greater reported attentional flexibility used more distraction strategies including playing with alternative objects. In the current study, distraction was not related to the LPP, and must therefore be meaningfully distinguished from alternative activity use. One possible explanation can be drawn from Babb *et al*.'s (2010) definition of coping flexibility: active adaptation to an uncontrollable situation. Engagement in alternative activities may signify attentional flexibility since it requires active adaptation as opposed to the passive gaze avoidance used in distraction. Furthermore, reappraisal is an effortful process, particularly for children. Use of active ER behaviors may reflect an underlying emergence of effortful ER that is also reflected in reappraisal ability during the cognitive reappraisal task.

While reappraisal-induced reductions in the LPP were associated with alternative activity use, there were no significant associations with other strategies or with strategies thought to be less adaptive, like prohibited object engagement. A small number of maladaptive strategies were observed, thus preventing a thorough examination of the links between the LPP and these strategies. However, this null effect adds credence to the idea that the LPP may be most sensitive to individual differences in flexibility rather than being an indicator of the tendency to use relatively adaptive or maladaptive discrete strategies. However, further research is needed to understand the factors that contribute to individual differences in the sensitivity of the LPP to reappraisal. In a previous study using the sample from which the current subsample was drawn, sensitivity of the LPP to reappraisal was related to maternal report of child anxiety (DeCicco *et al*., 2012), as well as broad symptoms of anxiety-depression (DeCicco *et al*., in press; Dennis & Hajcak, 2009). In addition, a longitudinal link between the LPP and alternative activities was significant for the DT, but not the WT. This raises the possibility that contexts that are more likely to change over development, such as those including complex social interactions, may be more difficult to predict from discrete neural responses. This highlights the importance of systematically considering the context of ER in future studies.

Individual differences in LPP reappraisal sensitivity may be related to the role of social context in developmental trajectories of ER. For instance, child ER can be improved by parental social scaffolding (Morris, Silk, Morris, Steinberg, Aucoin & Keyes, 2011), a context that is present in a child's everyday life. Methodologically, it is important to consider that some 5- to 7-year-olds can reappraise in an unfamiliar laboratory task, while others need a more ecologically valid context to demonstrate their ability. Another important consideration is that, due to the longitudinal nature of this study, children's memories that negative situations were rectified during T1 may have influenced their behaviors during T2, reducing emotion induction effects. Moreover, object engagement was negatively correlated with distraction and alternative activity use during T1 but not T2, perhaps due to the overall decrease in attention-shifting strategies resulting from familiarity with the task. However, despite the potential impact of attenuated emotion induction at T2, the LPP at T1 still predicted regulatory behavior two years later.

The current study constitutes a crucial first step in examining whether the LPP can be used as a neurocognitive indicator of ER capacity that predicts regulatory behaviors and emotional adjustment across development. Current findings suggest that the LPP may have particular utility as a neurocognitive measure of flexibility, a core component of positive emotional adjustment.

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## Appendix

| Behavior | Task(s) | Description |
|---|---|---|
| Prohibited object engagement | WT only* | This strategy included violations of the task rule to wait to open the wrapped gift, as well as looking at, visually fixating on, attempting to touch, or interacting with the prohibited object. |
| Object engagement | DT and WT | This strategy entailed moving the focus of attention onto the undesired object (boring/broken toy) either verbally or behaviorally. |
| Social engagement | WT only** | This strategy included speaking to the parent or asking questions specifically pertaining to the prohibited object such as asking the parent to speculate about the contents of the gift. |
| Distraction | DT only | This strategy involved moving the focus of attention onto something unrelated to the task, without active engagement with another activity. Examples included staring into space for more than 3 seconds or covering the face with hands. |
| Alternative activities | DT and WT | This strategy involved actions that moved the focus of attention away from the task either verbally or behaviorally. Examples included singing or playing with surrounding objects. In the WT, a participant talking to their caregivers about anything except the task or the prohibited object was considered an alternative activity. |

DT = Disappointment task. WT = Waiting task. *DT did not involve child exposure to their desired toy. **DT did not include the parent.