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Expressive Suppression Downregulates Negative Emotion for Children: An ERP Study

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Abstract

Event related potentials (ERPs), specifically the late positive potential (LPP), are known to be sensitive to expressive suppression (ES) in adolescents and adults. Although previous studies examined the neural characteristics of ES, few used a sample of children. This is the first study to explore the neural correlates of ES in children. We tested and provided neurological evidence of the characteristics of ES in children. ERPs of 30 healthy children (10 - 12 years old) performing an ES task were recorded. We found that decreased LPPs were evoked for expressive suppression condition (ESC) compared to negative view condition (NV) in all time windows. Middle and late windows did not show different LPPs between ESC and neutral view condition (NEV). These findings demonstrate that ES might effectively downregulate negative emotional experience for children. The nature and utility of ES as a specific form of emotion regulation in children are discussed.

Keywords

Children, Emotion, Expressive Suppression, Late Positive Potential, Event Related Potentials

1. Introduction

Humans can monitor, evaluate, and revise their emotional responses through emotion regulation (Gross, 1998). Emotion regulation has a profound impact on children's social competence, psychological well-being, and behavioral problems (Gross & Cassidy, 2019). Expression suppression strategy is one of the common emotion regulation strategies used by children (Gross & Cassidy, 2019). However, there is less research on whether children can effectively downregulate nega-

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tive emotions by ES strategies.

ES means that an individual consciously suppresses the emotion that is going to happen or is happening (Gross & Levenson, 1993). According to the process model of emotion regulation, ES is a reaction-centric strategy. ES involves modifying the behavioral components of an activated emotional response (e.g., concealing facial expressions of fear).

Concealing emotional displays is often necessary for social functioning and for maintaining social relationships (Gross & Cassidy, 2019). Children and adults often hide their emotions (Gullone et al., 2010; Zimmermann & Iwanski, 2014). As children grow up to face an increasing number of social rules, they may need greater ES. Liu et al. (Liu et al., 2017) believed that 7 years old children self-report that sthey use ES to regulate emotions in daily life. Between the ages of 9 to 12 years, ES is used more and more frequently (Gullone et al., 2010). In summary, ES strategies are often used by children in late childhood to regulate emotion, so it is meaningful to explore whether ES can effectively downregulate negative emotions.

Event-related potentials (ERPs) have proven particularly useful in processes of emotion regulation. Specifically, a late positive potential (LPP), between 350 and 1500 ms post-stimulus onset, is larger for emotionally arousing as compared to neutral stimuli (Desatnik et al., 2017; Schupp & Kirmse, 2021). Numerous event-related potential studies showed that LPP is larger for pictures in high emotional arousal compared to low arousing images (Schupp & Kirmse, 2021).

The LPP is a positive-going slow-wave arising approximately 350 ms after picture onset (Desatnik et al., 2017). Considerable evidence from emotion studies indicated that LPP is a viable neurophysiological measure for studying emotion and emotion regulation across the lifespan (Hajcak et al., 2010; Moran et al., 2013). Compared to neutral emotional stimuli, enhanced LPP amplitudes are evoked by negative emotional stimuli (Zhang et al., 2013). Hajcak and Dennis (Hajcak & Dennis, 2009) found that similar to adults, children produce increased LPP in response to emotional images relative to neutral ones. However, LPP activity in children seems to be more concentrated in occipital regions as opposed to the more centrally focused LPPs found in adults and adolescents (DeCicco et al., 2014; Kujawa et al., 2012).

The LPP is associated with emotion regulation effect. Specifically, Hajcak and Dennis (Hajcak & Dennis, 2009) found that the cognitive reappraisal strategy can regulate the LPP of children (5 - 8 years old) in the middle time window (600 - 1000 ms) and that the LPP after neutral interpretation is significantly lower than that after negative interpretation. Li et al. (Li et al., 2020) also found that an ES strategy effectively attenuates the LPP of college students exposed to pleasant stimuli. A study by Desatnik et al. found that adolescents aged 12 - 17 years can use ES strategies to reduce LPP (Desatnik et al., 2017). Nevertheless, there are only a relatively small number of studies exploring ES in children, and further studies that combined neurophysiology are lacking (Gross & Cassidy, 2019). This study attempted to test and provide neurological evidence of the characteristics of ES in children. The LPP is widely proven to be an effective biomarker for individual emotion and emotional regulation (Desatnik et al., 2017; Hajcak et al., 2010). Although several studies examined the neural characteristics of ES (Desatnik et al., 2017), few used a sample of children.

The current study investigated whether ES can downregulate negative emotions in children and attempt to provide neurophysiological evidence for this. The ES paradigm developed by Desatnik et al. (Desatnik et al., 2017) was used. Specifically, we manipulated three experimental conditions: neutral view condition (NEV), negative view condition (NV), and expressive suppression condition (ESC). In NEV and NV, children passively watched neutral and negative pictures. In ESC, children were shown negative images and told not to show emotion-related expressions and sounds, to investigate whether the ES strategy was effective in a population of children by comparing the electrophysiological characteristics of different conditions.

The present study is the first to investigate the electrocortical reactivity to use ES strategy after viewing negative picture. We hypothesized that the amplitudes of LPP in ESC were smaller than those in the NV.

2. Methods

2.1. Participants

Participants were thirty 10 - 12 years old children ($M = 10.74$, $SD = 0.815$); 12 females and 18 males. Of the 34 children, four children were excluded due to excessive movement artifacts. All the children were recruited from a primary school in Dalian, China. All children were of normal intelligence, physically healthy, and had no history of psychopathology. Their parents provided informed consent before the experiment. All the children received a gift after the experiment.

We conducted sample size estimation using G*Power v.3.1 (Faul et al., 2007) to determine the number of participants sufficient to detect a reliable effect. For the repeated measurement analysis of variance applicable to this study, it is at the significance level $\alpha = 0.05$, and medium effect ($f = 0.25$), the total sample size predicted to reach 80% statistical power level is at least 29. A sample of 30 participants was adequate to reveal reliable results.

2.2. Stimuli

Stimuli were obtained from the International Affective Picture System (IAPS) and comprised of 25 neutral and 25 negative pictures. All pictures were evaluated by 29 children (aged 9 - 12 years) for valence and arousal using a seven-point scale from 1 (very unpleasant) to 7 (very pleasant) and 1 (very calm) to 7 (very excited), respectively. Neutral pictures had a mean valence of 4.00 ($SD =$ 1.28) and arousal of 2.98 ($SD = 2.00$). The negative pictures had a mean valence of 2.84 ($SD = 1.83$) and arousal of 4.39 ($SD = 2.16$). The ratings of negative and neutral pictures showed differences in valence ($t_{(28)} = 12.57$, $p < 0.001$, $d = 0.73$), and arousal ($t_{(28)} = -14.21$, $p < 0.001$, $d = 0.68$).

2.3. Procedures

Children were seated in a quiet and comfortable room. Their eyes were approximately 70 cm in front of the computer monitor. Pictures were presented on a black background using E-prime 2.0, software (Psychology Software Tools, Inc., Pittsburgh, PA, USA). There were six blocks in this study. The first block was neutral view condition, the second block was a negative view condition, and the third block was ESC. Then these blocks were repeated again.

In the NEV, participants were instructed to view 25 neutral images presented in random order. In the NV, the participants were instructed to view 25 negative pictures in random order. This is followed by the ESC. In this condition, participants were asked not to show their feelings after watching negative picture. They must make sure the experimenters could not see what they felt from their face and body. They were shown cameras at the top of the computer screen and were informed that the experimenters would be watching their responses. For all conditions, the participants completed three practice trials in which they were allowed to repeat if they wished.

Each trial in the neutral and negative conditions began with a white fixation cross that appeared at the center of the screen for 500 ms, followed by a 500 ms blank screen. Before another 500 ms blank screen, a neutral or unpleasant image was presented for 2000 ms. Each trial in the ESC began with a white fixation cross appearing at the center of the screen for 500 ms. The cross was followed by a 500 ms (“regulate”) window during which the words “不要表现出来 (don’t show your emotion)” appeared on the screen in white on a black background accompanied by a male or female voice (alternating) saying “don’t show.” This was followed by the presentation of the unpleasant image for 2000 ms which was followed by a 500 ms blank screen. Figure 1 shows the experimental procedure.

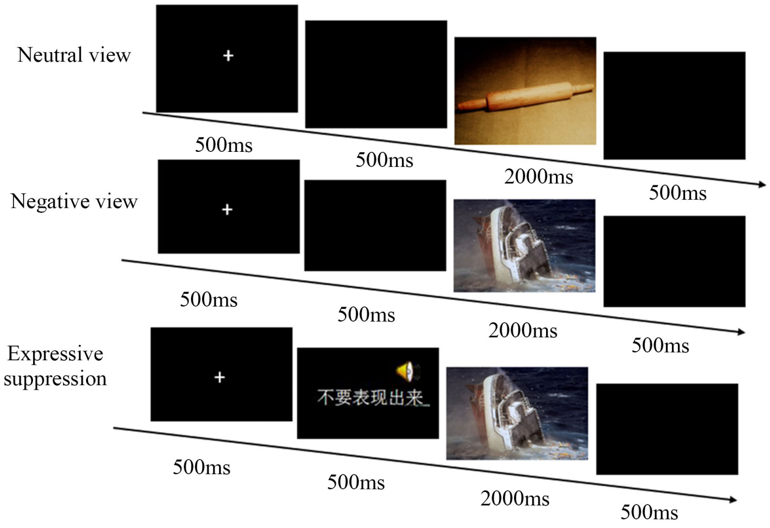

Figure 1. Schematic representation of the experimental procedure.

2.4. EEG Recording and Analysis

EEG was recorded from 64 active electrodes relative to the vertex (CPz) using an ANT amplifier (ANT Neuro EEGO Inc., Germany) at a continuous rate of 1000 Hz. Data were analog filtered 0.1 to 100 Hz. The sensor impedances were maintained at below 10 kΩ. Eye blinks and horizontal and vertical electrooculograms (EOG) were monitored using an electrode placed below the right eye.

Offline processing of EEG signal data was performed in MATLAB using the EEGLAB toolbox (Delorme & Makeig, 2004) and the ERPLAB toolbox (Lopez-Calderon & Luck, 2014). First, the data were down sampled to 500 Hz. Portions of the EEG containing large muscle artifacts or extreme offsets (identified by visual inspection) were removed. The EEG data were re-referenced to the average of the left and right mastoids. Then, each EEG was filtered with a 0.01 Hz high-pass and 30 Hz low-pass filters. Eye blinks and horizontal and vertical eye movements were corrected using independent component analysis (ICA). The EEG was then baseline-corrected (−200 to 0 ms). The EEG was segmented for each trial from negative 200 ms to 1600 ms relative to the stimulus onset. Artifacts were identified using the threshold criterion (±100 μV). Three participants were excluded from analysis due to loss of more than 50% of trails. In the final sample, on average 75.45% (SD = 12.82%); range 52.7% - 98%) of the epochs were retained. The epoch retention rate was independent of condition, participants' gender and age ($ps > 0.187$; repeated measures ANOVA). Following, we computed Cronbach's alpha estimates for all the ERP components analyzed in this study by treating the average amplitudes for the three conditions as items. Internal consistencies were good to excellent (alpha = 0.836 - 0.918) and above the recommended ERP reliability threshold (alpha = 0.70; (Clayson & Miller, 2017)).

ERPs were assessed by separately averaging trials for each condition. ERP components were quantified as the mean amplitude (μV) in the following electrode positions and time windows, chosen according to previous studies and visual inspection. The LPP was quantified as the mean amplitude at O1, O2, Oz, PO3, PO4 and POz, based on visual inspection of the scalp distribution and previous LPP studies with children. In accordance with previous child studies (Keil et al., 2022), we analyzed the LPP in three separate time windows at 350 - 600 ms (early window), 600 - 1000 ms (middle window) and 1000 - 1500 ms (late window).

2.5. Statistical Analyses

Partial eta-squared values were used to describe effect sizes. Mixed-design ANOVAs were computed to evaluate the effects of each Condition (NEV, NV, ESC) as within-subjects factors and Gender (boys, girls) as between-subjects factors on neural outcomes. For the LPP, we also included Time (350 - 600 ms, 600 - 1000 ms, and 1000 - 1500 ms) as a within-subjects factor in the analysis. For the sake of brevity, we reported follow-up tests only in case of significant or marginally significant effects involving Condition or Gender. In case of significant main effects involving Condition, we used post hoc Tukey tests. Simple effects analyses were used for follow-up testing of significant interaction effects. Measures of effect size for ANOVAs are expressed as η_p^2.

3. Results

The 3 (Condition: NEV, NV, ESC) × 2 (Gender: boys, girls) × 3 (Time: 350 - 600 ms, 600 - 1000 ms, 1000 - 1500 ms) mixed-design ANOVA with repeated measures on Time showed no significant effects involving Gender on LPP amplitudes, $Fs < 0.91$, $ps > 0.351$. LPP amplitudes differed according to Time, $F(1.11, 31.10) = 82.03$, $p < 0.001$, $\eta_p^2 = 0.746$, and Condition, $F(2, 56) = 22.58$, $p < 0.001$, $\eta_p^2 = 0.446$. NV showed higher LPP amplitudes than NEV and ESC (see Table 1). Time interacted with Condition, $F(3.02, 84.57) = 22.57$, $p < 0.001$, $\eta_p^2 = 0.446$. NV showed higher LPP amplitudes than NEV and ESC in all time windows ($ps < 0.043$, $ds > 0.42$). The early window showed higher LPP amplitudes in ESC compared to NEV, $p = 0.005$, $d = 0.40$. The middle window did not show differences between ESC and NEV, $p = 1$. The late window showed lower LPP amplitudes in ESC compared to NEV, $p = 0.004$, $d = 0.63$. The ERP waveforms in Figure 2 and Table 1 illustrate the interaction.

4. Discussion

The present study is the first to investigate the use of ES strategies in children to regulate negative emotions by ERPs. Negative pictures induced higher LPP amplitudes compared to neutral pictures. Importantly, children showed reduced LPP following ES, supporting expressive suppression as an effective emotion regulation strategy already in children. In accordance with our hypothesis, this suggested that LPP provides a measure of emotion regulation in children. The present study provided the first evidence that LPP amplitudes can be modulated via ES instructions earlier during late childhood than previously suggested in the literature (Desatnik et al., 2017). Taken together, the findings showed that 10- to 12-year-old children could use an ES strategy to effectively downregulate negative emotions. The present study extended previous findings regarding the neural correlates of emotion regulation in children.

Table 1. Means and standard deviations of LPP amplitudes in three conditions.

	NEV		NV		ESC	
	M	*SD*	*M*	*SD*	*M*	*SD*
Early LPP	13.16	8.09	20.73	9.30	16.43	8.26
Middle LPP	8.05	5.70	14.20	6.68	8.67	5.52
Late LPP	5.90	4.64	8.14	5.83	3.09	4.22

NEV, neutral view condition; NV, negative view condition; ESC, expressive suppression condition.

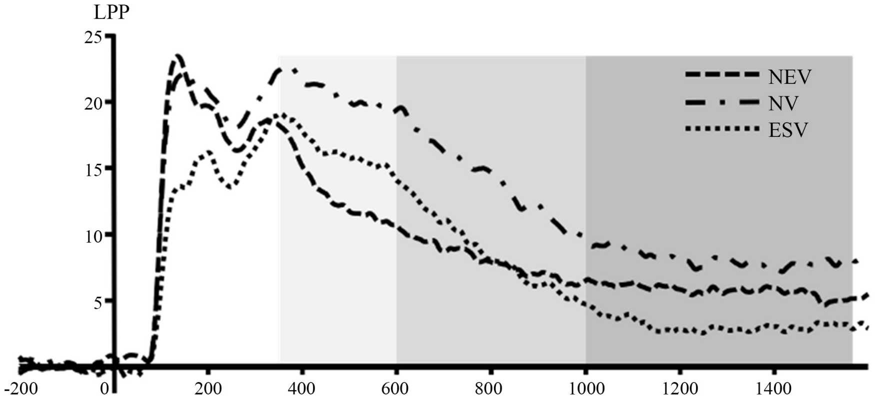

Figure 2. Expressive suppression related effects on LPP (averaged from O1, O2, Oz, PO3, PO4 and POz).

The present findings confirmed that, in line with previous studies (Hajcak & Dennis, 2009; Kujawa et al., 2012), negative images increased LPP compared to neutral images. These results supported the assumption that LPP was valid metric for exploring emotion regulation processes in late childhood. Meanwhile, ESC significantly reduced the LPP compared with NV. In addition, no LPP difference was noted between ESC and NEV. Consistent with previous studies on adolescents (Desatnik et al., 2017), these results confirmed the hypothesis that children could use ES to downregulate the LPP amplitude.

To examine the time course of LPP during ES in late childhood, we identified three-time windows (early: 350 - 600 ms, middle: 600 - 1000 ms, and late: 1000 - 1500 ms). In passive viewing conditions, we found that the LPP operated in ways similar to those seen in adolescents and adults: LPP amplitudes were larger for negative stimuli than for neutral stimuli (Krompinger et al., 2008; Zhang et al., 2013). The effect of emotion on LPP was apparent within all the time windows. In addition, the LPP amplitudes were maximal in the early window. These results are also consistent with those documented in studies of children (DeCicco et al., 2014).

Although our results demonstrate that children are able to use ES to reduce negative emotions, it is still necessary to consider the effects of ES on other psychological processes. There is evidence that expression suppression is associated with depressive and anxiety symptoms (Schäfer et al., 2017). According to the process model, part of the reason why ES is associated with poorer outcomes may be because it occurs later in the emotion-generative process (Gross, 2015). This may make it a more cognitively demanding form of emotion regulation, as it requires efforts to manage already activated emotional responses (Sheppes et al., 2014). As a result, efforts to suppress may interfere with other processes that require cognitive resources, including memory, problem solving, maintaining successful social interactions, and many other processes critical to children's development (Lantrip et al., 2016). However, research on the psychological mechanisms of ES associated with negative outcomes is lacking and more observational and experimental studies need to be designed.

This study had limitations worth noting. First, ES instructions were delivered in the form of an automatic visual and auditory cue that was not present in passive viewing conditions. This most likely influenced the early aspects of the trials. Future studies should devise better ways to manipulate subjects to use ES strategies. Second, we only used fear pictures to induce negative emotions, and other negative emotions need to be explored in the future. Third, future research could explore the effects on other cognitive functions following the use of ES to regulate negative emotions. An additional last limitation is related to the age range of participants in this study. We focused on the age range between 10 and 12. In order to further our understanding of change in emotion regulation associated with development, future studies should explore the neural correlates of emotion regulation strategies across broader age spans, or indeed, the entire life span.

5. Summary

In summary, the present study demonstrates that LPPs are sensitive to emotion regulation instructions in children. Furthermore, theses current findings support the idea that ES is effective in significantly modulating neural correlates of emotion regulation in children. In this study, a comprehensive analysis of ERP results shows that children are able to use ES strategy to successfully downregulate negative emotions.

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Compliance with Ethical Standards

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The experimental protocol was approved by the Liaoning normal University Ethics Committee.

Statement of the Individual Author's Contributions

Wen Liu, and Yuyang Han contributed to conception and design of, or acquisition of data or analysis and interpretation of data; Xingnan Fan, Chao Gao and Fang Liu contributed to the Part of draft the article or revised it critically for important intellectual content. Wen Liu and Zhongqing Jiang contributed to the final revised and approval of the version to be published.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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