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Brain potentials during affective picture processing in children

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ABSTRACT

In adults, emotional (e.g., both unpleasant and pleasant) compared to neutral pictures elicit an increase in the early posterior negativity (EPN) and the late positive potential (LPP); modulation of these ERP components are thought to reflect the facilitated processing of, and increased attention to, motivationally salient stimuli. To determine whether the EPN and LPP are sensitive to emotional content in children, high-density EEG was recorded from 18 children who were 5–8 years of age (mean age = 77 months, SD = 11 months) while they viewed developmentally appropriate pictures selected from the International Affective Picture System. Self-reported ratings of valence and arousal were also obtained. An EPN was not evident following emotional compared to neutral pictures; however, a positivity maximal at occipital–parietal recording sites was increased from 500 to 1000 ms following pleasant pictures and from 500 to 1500 ms following unpleasant pictures. Comparisons between the EPN and LPP observed in children and adults, and implications for developmental studies of emotion, are discussed.

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Studies have begun to examine neural correlates of emotional processing in children—especially with regard to the development of psychopathology (Cole et al., 2004; Lewis et al., 2006, 2007; Lewis and Stieben, 2004). For instance, studies that employ functional magnetic resonance imaging (fMRI) have indicated that anxious children might be characterized by abnormal amygdala response to threatening stimuli (McClure et al., 2007; Thomas et al., 2001a). Because of its excellent spatial resolution, fMRI is ideal for elucidating which neural structures are both implicated in emotional processing *and* sensitive to individual differences—work that has important implications with regard to understanding the abnormal neural architecture related to the development of psychopathology (Cole et al., 1994; Dahl, 2001, 2003; Pollak, 2003, 2005; Stieben et al., 2007).

In addition to fMRI, electrocortical measures of brain function can also be used to study abnormal emotional processing relevant to the development of psychopathology. For example, using event-related potentials (ERPs), several studies have provided evidence that early adverse experience alters neural responses to negative facial expressions within the first 300 ms of perceptual processing (Cicchetti and Curtis, 2005; Parker and Nelson, 2005; Pollak et al., 2001; Pollak and Tolley-Schell, 2003) and at later, more elaborated stages of processing (Pollak et al., 2001). Such findings have the potential to reveal specific mechanisms by which early experience impacts emotional processing and adjustment, ones that neural measures with less fine-grained temporal resolution may not reveal. Therefore, ERPs provide a powerful measurement tool for capturing neural activity related to emotional responding.

In fact, many studies have examined ERP responses to complex images from the International Affective Picture System (IAPS; Lang et al., 2005) to study both emotion and emotion regulation in adults (Cuthbert et al., 2000; Dunning and Hajcak, in press; Foti and Hajcak, 2008; Foti et al., in press; Hajcak and Olvet, 2008; Hajcak et al., 2006; Hajcak and Nieuwenhuis, 2006; Sabatinelli et al., 2007; Schupp et al., 2000, 2003a,b, 2004a,b). The IAPS is a standardized set of hundreds of color photographs that are designed to evoke a range of emotional responses; content ranges from unpleasant (e.g., threat scenes, mutilation), to neutral (e.g., household objects) to pleasant (e.g., erotica, sports scenes). Particularly relevant to the current study, both pleasant and unpleasant IAPS stimuli are associated with increases in two particular ERP components in adults: the early posterior negativity (EPN) and the late positive potential (LPP).

Approximately 150 ms following the onset of emotional (e.g., both pleasant and unpleasant) stimuli, the EPN becomes more negative, and this difference is maximal approximately 200–300 ms after stimulus onset (Schupp et al., 2003a,b, 2004b). This enhancement of the EPN is more pronounced for pictures with higher levels of emotional arousal, such that erotic stimuli and mutilations produce the largest posterior negativities (Schupp et al., 2003a,b). The EPN is prominent at bilateral temporo-occipital sites (Junghofer et al., 2006; Schupp et al., 2004a,b, 2003a,b). In

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light of this scalp distribution, it is believed that the EPN originates from the visual cortex and reflects increased activity in relatively early visual processing (Schupp et al., 2003b, 2004c).

Following the EPN, emotional stimuli elicit a rather sustained positive deflection in the ERP that has been referred to as the late positive potential. Specifically, the LPP is evident approximately 200–300 ms after the onset of pleasant and unpleasant compared to neutral stimuli, and is maximal at midline parietal recording sites (Cuthbert et al., 2000; Foti and Hajcak, 2008; Foti et al., in press; Hajcak and Olvet, 2008; Hajcak et al., 2006; Hajcak and Nieuwenhuis, 2006; Keil et al., 2002; Schupp et al., 2000, 2004b). In terms of its initial timing and scalp topography, the LPP resembles the classic P300 which appears larger following the presentation of task-relevant stimuli (Johnson, 1984, 1986; Magliero et al., 1984; Squires et al., 1977; Sutton et al., 1965). However, whereas the P300 appears as a more transient response, the LPP is sustained for as long as the affective stimulus is presented (Cuthbert et al., 2000), and is even evident following stimulus offset (Hajcak and Olvet, 2008). The increased LPP following emotional compared to neutral stimuli is observed at both posterior and anterior recording sites after approximately 1000 ms of stimulus presentation (Foti and Hajcak, 2008; Hajcak and Olvet, 2008; cf., Cuthbert et al., 2000). Just as the P300 appears to index transient increases in attention toward targets, the LPP might reflect the continued increase in attention toward emotional stimuli. In one combined fMRI/ERP study, the LPP correlated with neural activity in the lateral occipital, inferotemporal, and parietal visual areas, supporting the notion that it reflects increased perceptual and/or attentional processes engaged by motivationally relevant, emotional stimuli (Sabatinelli et al., 2007).

Although many studies in adults have examined ERP responses to the IAPS, comparable data in children has not been reported. In fact, the IAPS have not been used extensively in children. In one study, McManis et al. recorded self-report and peripheral psychophysiological responses from 7 to 10-year-old children while they viewed a developmentally appropriate subset of images from the IAPS. McManis et al. found that activity of the corrugator muscle and heart rate deceleration varied as a function of IAPS picture content in children, whereas skin conductance and startle reactivity were sensitive to picture content in female, but not male, children (McManis et al., 2001). A more recent study by Sharp et al. (2006) suggest that children's self-reported ratings of IAPS followed a similar pattern as that found in adults. Thus, there is initial evidence that children generally respond to complex emotional stimuli in a similar manner as adults, and these data further suggest that developmentally appropriate images from the IAPS can be used to assess emotional processing in developmental studies.

Because of their superior temporal resolution and relative ease to record from younger participants, ERPs might be ideal for examining relatively early neural responses to emotional stimuli in children (cf., Banaschewski and Brandeis, 2007). The EPN and LPP might be useful measures for studying both normative emotional development—and the development of psychopathology. The goal of the present study was to provide an important first step toward this aim—and to examine ERPs elicited by the IAPS in children. In an effort to examine whether children, like adults, will be characterized by a modulation of early (EPN) and late (LPP) ERPs to emotional compared to neutral IAPS images, the present study recorded ERPs from twenty five 5–10-year-old children. We chose this age range because early school age is a period marked by the cognitive and neural development needed to perform well under the attentional processing demands imposed by the experimental task (Casey et al., 2000). Participants passively viewed 90 developmentally appropriate IAPS images (30 pleasant, 30 neutral, and 30 unpleasant), and later provided valence and arousal ratings for each picture. Based on adult work, we predict that both the EPN and LPP would be enhanced for pleasant and unpleasant compared to neutral images. Based on previous studies, we predicted that children would rate pleasant and unpleasant images as more arousing than neutral, and would increase ratings of pleasantness from unpleasant to neutral to pleasant images.

1. Method

1.1. Participants

Twenty-five children (12 male, 13 female) and their caregivers provided informed consent to participate in the current study. Data from two subjects (both female) were excluded due to poor quality EEG recording, and data from 5 of the oldest remaining subjects were not included in these analyses so as to increase the homogeneity of age among the subjects. Thus, the final sample was comprised of 18 children who were 5 to 8 years of age; this sample included 9 males (mean age = 79.56 months, SD = 9.58 months) and 9 females (mean age = 74.56 months, SD = 12.31 months). All participants' families were paid $50 for their participation.

1.2. Stimulus materials

A total of 90 developmentally appropriate pictures were selected from the International Affective Picture System (IAPS; Lang et al., 2005); of these, 30 depicted pleasant scenes (e.g., smiling faces, fun scenes depicting sports, family, and animals), 30 depicted neutral scenes (e.g., neutral faces, household objects), and 30 depicted unpleasant scenes (e.g., sad/angry faces, wreckages, aggressive/attack pictures).[1] As a general criterion, the authors selected pictures that children might see either on television or in the news; erotica and mutilation pictures were not included. In terms of normative *adult* ratings (Lang et al., 2005), the picture categories differed in terms of valence ratings ($M = 7.45$, SD = 0.58, for pleasant picture content; $M = 5.29$, SD = 0.74, for neutral picture content; and $M = 3.36$, SD = 0.73, for unpleasant picture content). In addition, the emotional pictures were reliably higher on normative arousal ratings ($M = 4.76$, SD = 0.75, for pleasant picture content; $M = 5.70$, SD = 0.69, for unpleasant picture content; and $M = 2.81$, SD = 0.65, for neutral picture content). Note that these scores represent ratings that range from 1 to 9, where 9 would reflect extreme pleasantness and high arousal. Although we selected IAPS that were developmentally appropriate, the normative adult valence and arousal ratings of stimuli used in the current study are similar to those reported in existing studies on the LPP in adults (Bradley et al., 2007; Cuthbert et al., 2000; Foti et al., in press; Hajcak et al., 2007; Hajcak and Olvet, 2008; Schupp et al., 2004b).

The task was administered on a Pentium D class computer, using Presentation software (Neurobehavioral Systems, Inc.; Albany, CA) to control the presentation and timing of all stimuli. Each picture was displayed in color and occupied the entirety of a 19-in. (48.26 cm) monitor. At a viewing distance of approximately 24 in. (60.96 cm), each picture occupied approximately 40° of visual angle horizontally and vertically.

1.3. Procedure

After a brief description of the experiment, electroencephalograph (EEG) sensors were attached and the subject was given detailed task instructions. Subjects first viewed a practice series of pictures as they were displayed on the screen. Fifteen pictures were randomly selected for each experimental block, with a total of 6 blocks. Thus, each of the 90 pictures, randomly selected, was displayed once. The order of picture presentation was completely random such that there would be no confound of preceding picture type. At the beginning of each block, an instruction was presented for 2000 ms ("Simply view these pictures"). Each picture was presented for 2000 ms, and a fixation mark (+) was presented for 500 ms between each picture.

Next, all participants were asked to rate each picture on the valence and arousal scales of the self-assessment manikin (Lang, 1980; Lang et al., 2005). An abbreviated SAM scale was used that ranged from 1 to 5, rather than the standard 1 to 9 range used in adult studies. The valence scale was presented as an analogue scale that depicts five characters who range from happy to unhappy; below this scale are the numbers '1' through '5' ('1' corresponded to the happiest figure, '5' to the least happy figure, and '3' is located between the previous two). Participants were told to rate each picture on this scale based on how happy or sad it made them feel. The arousal scale of the self-assessment mannequin depicts five characters who appear

[1] The number of the IAPS pictures used were: unpleasant (1050, 1120, 1201, 1300, 1321, 1930, 2120, 2130, 2688, 2780, 2810, 2900, 3022, 3230, 3280, 5970, 6190, 6300, 7380, 9050, 9250, 9404, 9421, 9470, 9480, 9490, 9582, 9594, 9600, 9611); Neutral (5220, 5711, 5740, 5750, 5800, 5820, 7000, 7002, 7004, 7006, 7009, 7010, 7025, 7031, 7035, 7041, 7050, 7080, 7090, 7100, 7140, 7150, 7175, 7190, 7224, 7233, 7235, 7236, 7595, 7950); pleasant (1460, 1463, 1601, 1610, 1710, 1750, 1811, 1920, 1999, 2070, 2091, 2165, 2224, 2311, 2340, 2345, 2791, 4603, 5831, 7325, 7330, 7400, 7502, 8031, 8330, 8380, 8461, 8490, 8496, 8620).

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