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The time course of social-emotional processing in early childhood: ERP responses to facial affect and personal familiarity in a Go-Nogo task☆

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Abstract

To date, little is known about the neural underpinnings of social-emotional processes in young children. The present study investigated the time course of children's ERP responses to facial expression and personal familiarity, and the effect of these variables on ERP measures of effortful attention in a Go-Nogo task. Dense-array EEG was collected from 48 4–6-year-old children who were presented with pictures of their mothers' and strangers' happy and angry faces. ERPs were scored following face presentation and following a subsequent cue signaling a Go or Nogo response. Responses to face presentation showed early perceptual components that were larger following strangers' faces, suggesting facilitated rapid processing of personally important faces. A mid-latency frontocentral negativity was greatest following angry mothers' faces, indicating increased attentional monitoring and/or recognition memory evoked by an angry parent. Finally a right-lateralized late positive component was largest following angry faces, suggesting extended processing of negatively valenced social stimuli in general. Following the Go-Nogo response cue, a right-lateralized mid-latency negativity thought to measure effortful attention was larger in Nogo than Go trials, and following angry than happy faces, possibly reflecting increased effortful control required in those conditions. The present study suggests that overlapping but differentiated networks for both rapid and elaborative processing of important socio-affective information are established by 4–6 years. Moreover, the extended spatial and temporal distribution of components suggests a pattern of response to social stimuli in which more rapid processes may index personal familiarity, whereas temporally extended processes are sensitive to affective valence on both familiar and unfamiliar faces.

Keywords: ERP; Development; Emotion regulation; Emotion processing; Social cognition; Face processing

1. Introduction

1.1. Overview

Social-emotional information processing, and the regulation of social-emotional responses, are currently of great interest in both developmental psychology and social cognitive neuroscience (Adolphs, 2002; Blair, Morris, Frith, Perret, & Dolan, 1999; Cole, Martin, & Dennis, 2004; Gross, 2002). The emergent field of developmental social cognitive neuroscience draws on behavioral and neuroscientific research to better understand the neural underpinnings of such processes as they emerge in childhood and adolescence. Yet studying the neural correlates of children's social-emotional functioning is fraught with methodological challenges (for review, see Paus, 2005). To overcome these difficulties, the use of simple, salient stimuli and simplified task parameters, as well as non-invasive methods, are required. The present study measured event-related potentials (ERPs), using personally salient emotional stimuli in an attentionally demanding task. In order to capture some of the dynamism and complexity of cognitive processes in children, we took a temporal distributional approach to ERP analysis (as recommended by Picton et al., 2000). Rather than looking at discrete components thought to mark a single perceptual or cognitive process, a temporal distributional approach entails looking at

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a range of ERP components at a number of time-points and scalp locations to investigate patterns of cortical activation over time.

Within the field of social cognitive neuroscience, considerable interest has focused on neural processing of facial expression and identity/familiarity, as both convey important social information. It has been proposed that, in adults, the processing of facial affect and identity is subserved by overlapping (Calder & Young, 2005) and mutually interacting (Vuilleumier & Pourtois, 2007) networks. These networks include posterior perceptual regions that are responsive to emotional expression and/or identity and personal familiarity (Ganel, Valyear, Goshen-Gottstein, & Goodale, 2005; Henson et al., 2003; Winston, Henson, Fine-Goulden, & Dolan, 2004), and frontal regions that mediate processing of socially relevant information (Adolphs, 2002; Gobbini & Haxby, 2007; LaBar, Crupain, Voyvodic, & McCarthy, 2003). Furthermore, a body of evidence suggests that, in adults, frontal responses to facial affect may be lateralized, with greater right-hemisphere responses to stimuli that elicit negative affect (see Davidson, 2004) and/or response tendencies associated with withdrawal or avoidance (Harmon-Jones, 2004). The localization of social-emotional processes may correspond to temporal patterns as well, with posterior regions that mediate stimulus evaluation recruited earliest, and frontal regions implicated in extended processing and control becoming activated somewhat later (Adolphs, 2002). In adults, this real-time sequence of face processing thus appears to span rapid, relatively automatic perceptual responses as well as slower, learned, context-dependent "person knowledge" and explicit monitoring of one's own affective and behavioral responses (e.g. Dolan, 2002; Gobbini & Haxby, 2007; Lewis, 2005). However, the developmental schedule at which such spatiotemporal patterns emerge remains unknown.

Our goal was to measure a spectrum of ERP components, tapping rapid and extended responses to social-emotional stimuli, in early childhood, when social-emotional response repertoires are still developing. In keeping with the Interactive Specialization (IS) model of brain development (e.g. Johnson, 2001; Johnson et al., 2005) we assumed that cognitive functions are emergent processes arising from interactions among brain regions as well as between brain and environment. At different stages of development, social-emotional processing networks may be tuned to different aspects of facial affect and familiarity (e.g. Carver et al., 2003). We were interested in cortical responses to familiar and unfamiliar social stimuli in the kindergarten and early school years, a time when new skills for self-regulation are consolidating and social experience is broadening (Jones, Rothbart, & Posner, 2003; Prencipe & Zelazo, 2005; Zelazo, Müller, Frye, & Marcovitch, 2003). In particular, we were interested in children's differing responses to emotional expression on personally important, "overlearned" faces of mothers compared with emotion on unknown faces. Using a single paradigm, we aimed to address two sets of questions and hypotheses. The first concerned evaluative and regulatory responses to facial expression on mothers' and strangers' faces in 4–6-year-old children. The second concerned the impact of these responses on deliberate attentional processes recruited for achieving a specified goal.

1.1.1. Facial expression and familiarity in development

A substantial body of research suggests that facial expression is central to socialization processes that scaffold children's emotional development (de Haan, Belsky, Reid, Volein, & Johnson, 2004; Malatesta-Magai et al., 1994). In particular, smiling faces signal encouragement and angry faces are thought to signal the need to stop or change a behavior (Blair et al., 1999; Hare, Tottenham, Davidson, Glover, & Casey, 2005). The identity of the expressive face is also important to a child's well-being, as it is caregivers who routinely respond to children's behavior with angry and happy expressions. Thus, emotional expressions on personally important faces may be particularly salient to young children.

1.1.2. Cortical regions mediating social-emotional processing

A number of brain regions, which are linked to the amygdala and associated with social-motivational processing, discriminate personal familiarity and emotional expression in adults. Haxby and colleagues (e.g. Gobbini & Haxby, 2007) have proposed a set of core and extended networks for face processing. Core regions include the fusiform and lingual gyri, which mediate rapid perceptual processing (Ganel et al., 2005; Pessoa, McKenna, Guttierez, & Ungerleider, 2002; Vuilleumier & Pourtois, 2007; Winston et al., 2004), and have been found to be responsive to the salience of facial stimuli (Ganel et al., 2005; Pessoa et al., 2002; Surguladze et al., 2003; Vuilleumier, Richardson, Armony, Driver, & Dolan 2004). Networks for extended social and emotional processing include prefrontal regions, such as anterior cingulate cortex (ACC) and ventral prefrontal cortex (V-PFC). A number of neuroimaging studies have shown regions of V-PFC and ACC to be implicated in emotional feeling, evaluation of social feedback, attachment, empathy, self-regulation, and "person-knowledge" evoked by images of personally important faces (Allman, Hakeem, Erwin, Nimchinsky, & Hof, 2001; Blair et al., 1999; Dolan, 2002; Gobbini & Haxby, 2007; Gobbini, Leibenluft, Santiago, & Haxby, 2004; Leibenluft, Gobbini, Harrison, & Haxby, 2004; Nitschke et al., 2004; Ochsner et al., 2004; Rolls, 2007). Convergent evidence suggests that, although specific perceptual and prefrontal cortical regions may play different roles in social-emotional processing, all of these regions participate in networks that are responsive to the motivational salience — related to emotional expression and/or familiarity — of a face.

Although there is a paucity of neuroimaging (fMRI and PET) studies localizing precise regions responsive to faces in young children, a substantial body of developmental research using event-related potentials (ERPs) has mapped specific ERP components that are responsive to either facial emotion or the personal familiarity of faces. Moreover, in both adults and children ERP studies have enabled development of fine-grained models of the time course of face processing. Below we review the ERP components responsive to facial emotion, facial identity in general, and facial salience/familiarity in particular, as well as social-emotional processes thought to be indexed by such components.