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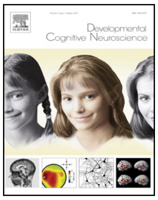

The neuropsychology of infants' pro-social preferences

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ABSTRACT

The current study is the first to investigate neural correlates of infants' detection of pro- and antisocial agents. Differences in ERP component P400 over posterior temporal areas were found during 6-month-olds' observation of helping and hindering agents (Experiment 1), but not during observation of identically moving agents that did not help or hinder (Experiment 2). The results demonstrate that the P400 component indexes activation of infants' memories of previously perceived interactions between social agents. This leads to suggest that similar processes might be involved in infants' processing of pro- and antisocial agents and other social perception processes (encoding gaze direction, goal directed grasping and pointing).

1. Introduction

Pioneering work by Premack and Premack (1997) demonstrated that 1-year-old infants attribute goals to animated agents helping or hindering each other, suggesting that these events are valued as positive and negative by the infants. This initial finding has been replicated and extended in several ways. Infants from 3 months of age express different preferences for animated agents that either help (pro-social) or hinder (anti-social) another geometric shape from climbing a hill (Hamlin et al., 2010). At this age infants look longer toward the helper than the hinderer, the effect being driven by a tendency to avoid looking at the anti-social agent. At 6 months, once infants' own manual capabilities have developed, infants systematically reach for pro-social agents when given a choice between a helper and a hinderer (Hamlin et al., 2007).

These initial pro-social preferences are more complex during the second half of the first year, being influenced by the social context in which an interaction occurs. Eight-month-olds prefer agents that act positively toward pro-social others and negatively toward anti-social others (Hamlin et al., 2011) whereas 9-month-olds prefer agents that treat similar others well and dissimilar others poorly (Hamlin et al., 2013a). At 1 year of age, infants not only attribute dispositional states to these interacting geometric shapes (Kuhlmeier et al., 2003) but also predict that agents will seek out others that have previously helped them (Fawcett and Liszkowski, 2012).

Scarf et al. (2012) have criticized the interpretation made by Hamlin et al. (2007). Instead of focusing on helping and hindering actions, Scarf et al. (2012) argue that infants prefer agents that are associated with positive events. Although this was a reasonable criticism of the original study this alternative interpretation cannot account for the conceptual replications of this method that

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have been performed using different stimuli (Hamlin et al., 2013b; Hamlin and Wynn, 2011), nor can it account for the subsequent more complex findings that infants' prosocial preferences are not rigid but depend on context (Hamlin et al., 2011, 2013a,b). In sum, there is currently substantial support for the notion that infants are able to interpret the interaction of animate agents as pro- or anti-social and that they use this information to guide their attention and reaching actions (for a review see Hamlin, 2013, 2014).

Several different interpretations have been proposed to account for infants' evaluation of actions' social valence. One possibility is that early-emerging mentalistic processes such as theory of mind and perspective taking (Kovacs et al., 2010; Onishi and Baillargeon, 2005; Southgate et al., 2007) mediate infants' pro-social preferences (Hamlin et al., 2013b). In fact, Hamlin et al. (2013b) suggest, based on modeling of empirical data, that 10-month-olds' pro-social preferences might involve second-order mental-state representations. That is, the goal of one agent relates to the intention of another (here referred to as the mentalistic account).

In adults and children the temporal parietal junction (TPJ), and with increased age the pre-frontal cortex (Kobayashi et al., 2007), are often implicated in mentalistic processes (Van Overwalle and Baetens, 2009), along with activation in the superior temporal sulcus (STS; Decety, 2011; Decety and Howard, 2013; Moll et al., 2002). Based on neuropsychological investigations of empathy conducted with adults and older children, alternative accounts are also possible. It is conceivable that some pro-social preferences are governed by lower level social perception processes, which relate actions to goals without the need for mentalizing (here referred to as the social perception account). Several indications suggest that these processes are organized by the STS without necessary involvement of higher cognitive functions. Adults showed more activation of the STS for animated geometrical shapes that appeared to interact in an intentional manner when compared to random movements, the activity being related to participant's ratings of intentionality (Castelli et al., 2000). In children, a recent fMRI study demonstrated that the STS (as one of several areas) is sensitive to perceived intentional harm in others (Decety et al., 2012). On a larger scale the STS is sensitive to body movement and goal directed actions such as reaching and looking, in addition to being sensitive to faces and emotional expressions in general (Allison et al., 2000).

The common denominator of the mentalistic and social perception accounts of processing of socially valenced actions is therefore the involvement of the STS. In infants it has been argued that the P400 ERP component is an index of STS activity (Gredebäck et al., 2010). There are several lines of enquiry that support this assumption. First of all, the P400 is often described as an infant version of the adult N170–N200 (along with the infant N290; de Haan et al., 2002; Nelson et al., 2006). This is based on studies that demonstrate infant P400 and adult N170–N200 in response to identical stimuli (Gredebäck et al., 2010; Senju et al., 2006) and the observation that similar manipulations alter the amplitude of infant P400 and adult N170–N200 components (Csibra et al., 2008). The N170–N200 in turn has been directly related to the STS via source localization and joint EEG, fMRI measures (Puce et al., 1998; Itier and Taylor, 2004; Dalrymple et al., 2011). On the basis of these arguments, and the observation that both accounts involve STS activity, we hypothesize that an infant P400 ERP component indexes processing of actions' social valence.

No study has investigated the neural correlates of prosocial preferences in young infants. However, a few studies have demonstrated that the infant ERP component P400 is related to processing of goal directed actions such as grasping (Bakker et al., in press) and pointing (Gredebäck et al., 2010; Melinder et al., in press), to emotional processing (Leppanen et al., 2007), biological motion (Reid et al., 2006) and gaze direction (Senju et al., 2006). In this context it is important to note that P400 amplitudes are larger for functional and goal directed actions (reaching for, or pointing toward objects, looking at interesting sights) than control stimuli that lack these object directed properties.

In this study we examine the neural correlates of infants' pro-social preferences by measuring EEG and target ERP components hypothesized to be sensitive to pro- and anti-social agents in the hill-climber paradigm (Hamlin et al., 2007). More specifically, 6-month-old infants were presented with two scenarios. In Experiment 1 one agent helps another agent (ball with eyes) to reach the top of a hill, whereas a different agent hinders the circular agent from reaching the top of a hill. In Experiment 2 one agent pushes up an inanimate ball (without eyes) to the top of the hill and another agent pushed the ball down the hill. Following these scenarios infants were presented with repeated images of the two agents that helped or hindered in Experiment 1 and moved up vs down in Experiment 2 (only one image was presented on each trial) and ERP components for these images were analyzed (for similar designs see Kaduk et al., 2013; Parise et al., 2008).

We hypothesize that P400 amplitudes will differ between pro- and anti-social agents (Experiment 1). Furthermore, given that prior studies have demonstrated larger amplitudes of P400 for congruent than incongruent pointing (Gredebäck et al., 2010) and gaze direction (Senju et al., 2006), as well as for upright over inverted biological motion point-light displays (Reid et al., 2006), we predict a larger P400 in response to agents that previously have helped over agents that previously hindered others. The hypothesized common denominator of previously and currently investigated social stimuli is a larger P400 amplitude for functional and typical social behavior (pointing to objects, looking at interesting sights, and agents that help others). No difference in P400 amplitudes is expected in Experiment 2 where the agent that is being helped and/or hindered is replaced by an inanimate ball.

We also analyzed the Nc component. This mid-latency component occurs approximately 300–700 ms after stimulus onset and is most prominent at fronto-central electrodes. It reflects attentional orienting to salient stimuli (Courchesne et al., 1981) and/or a general attentional arousal (Richards, 2003), as it is larger to infrequent than frequent stimuli (e.g. Courchesne et al., 1981) and is larger during periods of sustained attention (Richards, 2003). We examined the Nc in order to preclude attention and other