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How social is the chaser? Neural correlates of chasing perception in 9-month-old infants

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ABSTRACT

We investigated the neural correlates of chasing perception in infancy to determine whether animated interactions are processed as social events. By using EEG and an ERP design with animations of simple geometric shapes, we examined whether the positive posterior (P400) component, previously found in response to social stimuli, as well as the attention related negative fronto-central component (Nc), differs when infants observed a chaser versus a non-chaser. In Study 1, the chaser was compared to an inanimate object. In Study 2, the chaser was compared to an animate but not chasing agent (randomly moving agent). Results demonstrate no difference in the Nc component, but statistically higher P400 amplitude when the chasing agent was compared to either an inanimate object or a random object. We also find a difference in the N290 component in both studies and in the P200 component in Study 2, when the chasing agent is compared to the randomly moving agent. The present studies demonstrate for the first time that infants' process correlated motion such as chasing as a social interaction. The perception of the chasing agent elicits stronger time-locked responses, denoting a link between motion perception and social cognition.

1. Introduction

The human visual system not only detects physical structures in the environment but also their causal and social structures derived from motion information. When observing displays with simple geometrical shapes engaged in a variety of interactions such as fighting, dancing and chasing, adult observers consistently describe seeing animate, interacting entities with distinct goals and intentions (Heider and Simmel, 1944; for review, see Scholl and Tremoulet, 2000). This extraordinary ability of the visual system to derive such socially-rich information from relatively simple visual input reveals the primary and interdependent link between perception and social cognition in adulthood (Schultz et al., 2004). The fact that the discrimination of interacting and randomly moving objects takes place already at 3-months (Rochat et al., 1997), provides evidence that social categorization plays a fundamental role in how humans perceive their environment. However, to date no study has provided direct evidence that infants' social networks are being involved when observing interactions such as chasing, and the question whether social categorization through motion is present already early in infancy remains unanswered.

In the last decades, neural correlates involved in the perception of interactions have been much researched in adults. These studies find that areas used for perception of social stimuli also correspond when viewing animate interactions such as chasing. Much like the detection of biological motion, chasing elicits activation in the temporoparietal cortex, the posterior superior temporal sulcus (pSTS) and the angular gyrus (Castelli et al., 2000; Lee et al., 2012; Martin and Weisberg, 2003; Schultz et al., 2004) often lateralized to the right hemisphere (Gao et al., 2012; Schultz et al., 2005; Shultz et al., 2011).

Together, adult research on animacy perception suggests that observers, while watching lifeless geometrical shapes move, interpret them in terms of animacy and intentionality while the neurological correspondence of the areas associated with social stimuli support the idea that adults perceive these events as social.

For infants, much like adults, motion informs about the type of observed agents and events. For instance, studies examining infant visual attention have found that 3-month-olds orient and prefer to attend to displays where two discs are chasing compared to displays in which they are moving haphazardly bouncing off the boundaries of the screen (Rochat et al., 1997). Recent evidence (Galazka and Nyström, 2016) further suggests that infant visual

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attention within chasing interactions is largely accounted by the chaser, reflecting the developing sensitivity to kinematic information pertaining to interactions in limited visual displays (Galazka et al., 2014; Galazka and Nyström, 2016). But visual attention alone does not inform about whether infants attend to animated interactions because of their social narrative, or whether perceptual properties of the event alone cause the attentional shifts. One possibility is that areas responsive to social stimuli are elicited when infants observe these types of animated displays, much like in adults. Another possibility, however, is that infants' visual attention toward animated displays is due to lower level perceptual processes. For instance, objects that share the same motion trajectory (known as the classical Gestalt law of 'common fate') (Wertheimer, 1923/1938), objects that come close together, or objects that move contingently might capture visual attention more than randomly moving objects without interpreting them as social. In fact, very young infants attend to the features of chasing, such as goal-directed motion of one object toward another and acceleration more so than when these features are configured in a chasing motion (Frankenhuis et al., 2013). In the present article, we address this theoretical distinction by examining neural activation of social brain processes during chasing perception.

Infant neurological studies have previously used ERP component measures to determine the sensitivity to animacy and social information. One such ERP study found evidence for differential sensitivity to animate and inanimate motion in 9-month-olds (Kaduk et al., 2013). The findings suggested that by 9-months infants allocate more attention to an object moving inanimately than an animate object as evidenced by the increased negativity in the fronto-central Nc component, a mid-latency component that has been found to reflect general attentional arousal (Richards, 2003) as well as orientation to salient stimuli (Courchesne et al., 1981).

The processing of social information in infants, on the other hand, has been measured by the N290 and the P400 component, from now referred to as a N290/P400 complex. This latent component over the lateral posterior region has been argued to index pSTS activity (Gredebäck et al., 2010; Gredebäck and Daum, 2015) and in infants it has almost exclusively been associated with processing socially-valenced information (Gredebäck et al., 2015). For instance, in response to gestures that convey social meaning such as hands turned right side up in a 'give-me' gesture (Bakker et al., 2015), grasping (Bakker et al., 2014, 2016), pointing (Gredebäck et al., 2010; Melinder et al., 2015), gaze direction (Senju et al., 2006) and when observing biological motion (Reid et al., 2006). The infant N290/P400 complex, was found to parallel the N170 component in adults (Gredebäck et al., 2010; Senju et al., 2006) – a component associated in response to social stimuli such as human faces (Csibra et al., 2008). Unlike the infant P400 component, the P400 component in adult population has been associated with a wide range of factors such as visual ambiguity (Kornmeier and Bach, 2009), memory load (Klaver et al., 1999; Beuzeron-Mangina and Mangina, 2000), and attentional control (Falkenstein et al., 1999). Collectively, although no study has previously explored specific neural correlates to chasing, these studies suggest a unique set of ERP components to animated objects and social information in infancy.

The primary goal of the current two studies was to examine the neural correlates of chasing in infants by tapping the N290/P400 complex and the Nc component. In doing so, we gain insight into the underlying processes of social perception through motion.

Based on the two possible accounts of infant preference to animated displays, we hypothesize that if chasing interaction is interpreted as a social event the N290/P400 complex will be larger when chasing motion is compared to inanimate motion (Study 1) and when it is compared to animate but random motion (Study 2). Presence of the P400 component in these comparisons would speak in support of the social account suggesting that infants, like adults, process chasing as more than a set of motion cues. By contrast, presence of the attentional Nc component alone, would speak for a lower-level perceptual processing account, in which attention to motion parameters alone determines preference for the chasing event.

2. Study 1: chasing versus inanimate motion

2.1. Methods

To address the question of neural correlates underlying perception of a chasing interaction we presented 9-month-old infants with displays depicting two geometrical shapes involved in chasing, where one shape (a triangle or a rectangle) consistently moved toward another, while its partner (a grey circle) consistently moved away. In Study 1, the chasing motion was compared to inanimate motion. The inanimate motion depicted two objects (a rectangle if a triangle was shown during the chasing condition, or triangle otherwise, and a grey circle) moving at a constant speed along linear trajectories, only changing direction by bouncing off the display boundaries or two stationary objects in the display. Using a paradigm previously used for assessing ERP responses in young children (Gredebäck et al., 2015; Kaduk et al., 2013), we first presented the animations and then measured the ERP response to the still images of agents in the animation (a triangle and a rectangle).

2.2. Participants

Eighteen 9-month-old infants (6 female; mean age = 270 days; 8 months 29 days) were included in the final sample. All participants were full-term without known neurological or developmental disabilities. Additional 16 infants were tested but were not included in the final analysis due to failure in meeting the inclusionary criterion of minimum 10 artifact-free trials for each condition (a rectangle and a triangle). Although the exclusion criterion appears to result in a high drop rate, a recent meta-analysis on infant ERPs have determined a drop out rate of about 50% to be the standard in this type of paradigm with such young population (Stets et al., 2012). Participants were recruited from a list of parents who indicated interest in participating in research with their child. The majority of infants were primarily from white middle-class background living in a medium-sized European city. Studies were conducted in accordance with 1964 Declaration of Helsinki and all infants' parents provided written informed consent according to the guidelines specified by the local Ethical Committee. For their participation, parents received a gift voucher worth approximately 10 euro.

2.3. Stimuli and procedure

All infants began the procedure by observing video animations for each condition presented on a 17-in computer screen (Fig. 1). These video displays were directly followed by multiple static test images that were used to extract ERPs. In previous research, this procedure (video and test image) has been found to reliably influence ERPs in infants this age (Gredebäck et al., 2015; Kaduk et al., 2013).

The moving animations consisted of 10-s video presentations at the start of the procedure: 2 times the Chasing interaction and 2 times the Inanimate motion. The animations were created using Anime Studio Debut 10, an animation software (http://my.smithmicro.com/anime-studio-debut-10.html). All animations depicted a gray circle and either an orange triangle or a blue rectangle, where the triangle and the rectangle always belonged to one condition each (counterbalanced between subjects). All shapes were matched for luminosity and size, and all geometrical shapes