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The effect of biomechanical properties of motion on infants' perception of goal-directed grasping actions

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ABSTRACT

From a very young age, infants perceive others' actions as goal directed. Yet, the processes underlying this competence are still debated. In this study, we investigated whether (a) 4- and 6-month-old infants and adults discriminate the biomechanical properties of the human hand within an action context, (b) the manipulation of the biomechanics of hand movements has an impact on the ability to anticipate the goal of an action, and (c) the emergence of motor experience with grasping is related to infants' ability to discriminate the biomechanics of hand movements and to anticipate the action goal. The 6-month-olds discriminated between biomechanically possible and impossible grasps, and in some (but not all) instances they made more anticipatory gaze shifts toward the goal of the possible action. Both the 4- and 6-month-olds' processing of biomechanical properties of the hand were significantly related to their ability to anticipate the goal of a grasping action. Importantly, those 4-month-olds with higher precision grasping skills manifested faster anticipatory gazes toward the goal of the action. These findings suggest that multiple sources of information from an action scene are interdependent and that both perceptual information and motor experience with an action are relevant for on-line prediction of the final goal of the action.

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Introduction

On an everyday basis, we navigate a complex social world in which we interact with other social agents. Although we have direct access only to perceptual information about these agents' body movements in interaction with their environment, we rarely see them as simple moving bodies. We rather think of others in terms of their feelings and thoughts, and we interpret their behavior as goal directed (Csibra & Gergely, 2013; Rizzolatti & Craighero, 2004).

Despite extensive research on the early development of human action understanding (Csibra, 2003; Sommerville, Woodward, & Needham, 2005) and body perception (Slaughter, Heron-Delaney, & Christie, 2011), it is still of debate to what extent infants use information about the biomechanical properties of the human body for understanding others' actions. This study aimed to address this issue by investigating for the first time whether infants process the biomechanical properties of a salient part of the human body—the hand—and examining whether and how such processing affects infants' anticipation of the goal of a grasping action.

Evidence suggests that, by 6 months of age, infants perceive others' actions as goal directed (Woodward, 1998) and visually anticipate the finality of actions common in their experience (Ambrosini et al., 2013; Kanakogi & Itakura, 2011) even when the goal objects are not visually accessible (Daum & Gredebäck, 2011; Daum, Vuori, Prinz, & Aschersleben, 2009). Visual anticipation is specific to processing goal-directed actions rather than to processing motion (Cannon & Woodward, 2012). By 12 months of age, infants' understanding of others' actions develops further as they use a variety of social cues such as gaze direction (Woodward, 2003), emotions (Phillips, Wellman, & Spelke, 2002), and hand gestures (Woodward & Guajardo, 2002) in order to encode the action goal. Although processing actions as oriented toward a specific finality is not restricted to human agents (Csibra, 2003), infants seem to be particularly tuned to the actions of others (Falck-Ytter, Gredebäck, & von Hofsten, 2006).

For what concerns the early development of processing of human motion, the current evidence suggests a rather complex picture. By 7 to 9 months of age, infants are sensitive to the biomechanical properties of human bodies provided that stimuli are presented in motion rather than static. This is the case when both schematic (Ichikawa, Kanazawa, & Yamaguchi, 2011; Reid, Hoehl, Landt, & Striano, 2008) and real (Christie & Slaughter, 2010) body images are used as well for different methods such as EEG/ERP (electroencephalogram/event-related potential; Reid et al., 2008) and preferential looking (Christie & Slaughter, 2010; Mason & Bremner, 2013) paradigms. However, if dynamic human bodies are presented at a realistic size, even 6-month-olds process information about whole-body schema (Christie & Slaughter, 2009; Slaughter, Heron-Delaney, & Christie, 2011). The exploration of the underlying neural mechanisms suggests that at this age processing such information is slower and more effortful (Marshall & Shipley, 2009). Interestingly, the picture becomes even more complex when specific body parts, rather than whole-body schema, are taken into consideration. Morita and colleagues (2012) showed that 12-month-old infants and adults, but not 9-month-old infants, discriminated between biomechanically possible and impossible elbow movements. Conversely, Mason and Bremner (2013) found that 7- and 8-month-olds are able to discriminate even static images of biomechanically possible and impossible configurations of the hands. Thus, it seems that the analyzed body part also matters, with more salient body parts being favored over less salient ones. Taken together, this evidence suggests a relatively protracted development of the ability to process information about human motion and its biomechanical properties as well as body schema. Although more mature abilities are reached toward 7 to 9 months of age, evidence for important developmental shifts is recorded at around 4 to 6 months of age and may be critically related to processing specific body parts.

Indeed, from birth infants spend a large amount of time exploring their own and other people's hands (Van der Meer, 1997), and by toddlerhood the hands are the main focus of attention in exploring self and others' object-related actions (Yoshida & Smith, 2008). Hence, infants have more experience with these body parts in terms of both visual exploration and motor experience, which could in turn influence their sensitivity to violations in their biomechanical properties. Already by 5 or 6 months of age, infants rely on such information in processing others' goal-directed actions in which the hand is the main effector. For example, they show sensitivity to the goal structure of reaching and grasping