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Infants' understanding of actions performed by mechanical devices

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ABSTRACT

Recent research suggests that 9-month-old infants tested in a modified version of the A-not-B search task covertly imitate actions performed by the experimenter. The current study examines whether infants also simulate actions performed by mechanical devices, and whether this varies with whether or not they have been familiarized with the devices and their function. In Experiment 1, infants observed hiding and retrieving actions performed by a pair of mechanical claws on the A-trials, and then searched for the hidden toy on the B-trial. In Experiment 2, infants were first familiarized with the experimenter and the claws but not their function. In Experiment 3, infants were familiarized with the function of the claws. The results revealed that search errors were at chance levels in Experiments 1 and 2, but a significant proportion of the infants showed the A-not-B error in Experiment 3. These results suggest that 9-month-old infants are less likely to simulate observed actions performed by mechanical devices than by human agents, unless they are familiarized with the function of the devices so that their actions are perceived as goal-directed.

1. Introduction

The perception and representation of others' actions is crucial for understanding our social world. During everyday social exchanges we are able to effortlessly understand others' actions, implicitly know their intentions and desires, and automatically shape responses to these behaviors. Recent evidence suggests that infants begin to understand at least the goal-directed nature of actions by the second half of the first year, and perhaps even earlier (e.g., Csibra, Gergely, Bíró, Koós, & Brockbank, 1999; Király, Jovanovic, Prinz, Aschersleben, & Gergely, 2003; Luo, 2011; Luo & Baillargeon, 2005; Woodward, 1998, 1999; Woodward & Sommerville, 2000).

Many social neuroscientists suggest that there are neural mechanisms specialized for understanding and responding to observed actions (Decety & Sommerville, 2004; Frith & Frith, 2006; Grèzes, Frith, & Passingham, 2004; Saxe, Xiao, Kovacs, Perrett, & Kanwisher, 2004). These specialized mechanisms may help explain infants' precocious ability to understand others' actions. One unresolved issue, however, is whether the mechanisms involved with interpreting actions are reserved specifically for human actions or are applicable to a wider range of events. Press, Bird, Flach, and Heyes (2005) suggest that because humans have mental states and machines, mechanical devices, and other inanimate objects do not, a cognitive mechanism that responds specifically to human actions may be invaluable for inferring others' thoughts and discriminating animate from inanimate beings. Some researchers have suggested this is a crucial building block of social-cognitive development (Barrett, Todd, Miller, & Blythe, 2005; Rakison & Poulin-Dubois, 2001; Woodward, Sommerville, & Guajardo, 2001).

Several studies report evidence suggesting that infants' understanding of human actions does not extend to non-human agents. Woodward (1998), for instance, habituated infants to an experimenter reaching for one of two objects on a stage, then switched the objects' locations and

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measured looking times to the experimenter reaching for the original goal-directed object in its new location versus the other object in the previous location. Six-month old infants dishabituated to the agent reaching for the new object in the old location, but not to the old object in the new location. When a rod or mechanical claw was substituted for the experimenter, infants did not show differential looking to the two events. These results suggest that infants understand the actions of another person as goal directed, but do not understand the actions of an inanimate agent as goal directed. Similarly, Daum and Gredebäck (2011) found that infants are sensitive to the direction indicated by a hand grasp action by 7-months of age, but are not sensitive to the direction of a grasping claw device. Legerstee and Markova (2008) and Meltzoff (1995) reported that 10- and 18-month-old infants imitate the goal-directed intentions of a human actor, but they do not imitate analogous actions performed by a mechanical device. Likewise, a few studies demonstrate that adults do not respond the same way to actions modeled by non-human agents, such as robots or mechanical devices, as they do to actions performed by a human agent (Kilner, Paulignan, & Blakemore, 2003; Press et al., 2005; Tsai & Brass, 2007).

By contrast, a number of studies demonstrate that by 5-months of age infants use self-propulsion cues (Luo, Kaufman, & Baillargeon, 2009), and by 12-months use rational path selection cues (Csibra, 2008; Gergely, Nádasdy, Csibra, & Bíró, 1995) and a history of goal attainment (Kuhlmeier, Wynn, & Bloom, 2003) to guide their understanding of the actions of simple two-dimensional geometric shapes. For example, Luo (2011) and Bíró and Leslie (2007) showed, in adaptations of the Woodward (1998) paradigm, that at 3-months and 6-months, respectively, infants are sensitive to the goal-directed actions exhibited by a non-human agent if a sufficient set of animacy cues are present (e.g., self-propulsion, action variation with equifinality, and causal action-effect relations). Using the same paradigm, Hofer, Hauf, and Aschersleben (2005) reported that 9-month-old infants are sensitive to goal-directed actions executed by mechanical claws after a brief familiarization period where they were shown how the claws are operated by a human experimenter. These findings converge with those from adults who interpret the actions of moving geometric shapes as animate if their behavior involves certain sorts of motion, such as pursuit, avoidance, and goal-directedness (Gao, Newman, & Scholl, 2009; Heider & Simmel, 1944; Scholl & Tremoulet, 2000; Tremoulet & Feldman, 2000).

Currently, there is no clear consensus in the literature. Some researchers suggest that infants' understanding of others' actions and attributions of their intentions is specialized for the observation of human actions, while others suggest extension to non-human agents. There are, however, notable differences between the reported studies. Specifically, researchers who have reported that infants' understanding of actions extends to non-human agents have tended to provide infants with additional experience observing the agents act. For instance, it was only after infants had visual experience of a wooden rod moving freely (i.e., through self-propulsion), reaching for an object from multiple angles of approach, and lifting an object from a surface numerous times, that Bíró and Leslie (2007) were able to demonstrate that 6-month old infants are sensitive to the intentions of a non-human agent. Three-month old infants tested by Luo (2011) required similar "rich behavioral information" (p. 459). Accordingly, a key question in examining infants' understanding of the actions of human and non-human agents becomes, to what degree is previous visual experience necessary? In order to address this issue, the current experiments were conducted with mechanical devices, while varying the amount and form of previous experience infants had with the devices.

Our perspective on this issue is informed by the direct-matching hypothesis (Rizzolatti & Craighero, 2004; Rizzolatti, Fogassi, & Gallese, 2001), which suggests that observed actions are mapped directly onto our motor representation of the same action; an action and its effects are understood when its observation leads to simulation by the motor system (i.e., representing the actions of others through covert imitation). This hypothesis is a descendant of James's (1890) and Greenwald's (1970) ideomotor theories and Prinz's (1997) common coding theory. Interest in this approach heightened with the discovery of mirror neurons in primates, which discharge when a monkey either performs an action or observes another perform that action (Rizzolatti et al., 2001). Recent electrophysiological (Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995), neuroimaging (Decety et al., 1997), and behavioral (Bertenthal, Longo, & Kosobud, 2006; Brass, Bekkering, Wohlschläger, & Prinz, 2000) studies support the suggestion that a homologous mirror neuron system is functional in humans.

Several studies provide preliminary evidence that infants may be using motor representations to interpret others' actions in the form of correspondence between how they interpret others' actions and the actions they perform themselves. Sommerville, Woodward, and Needham (2005), for instance, reported that 3-month-old infants provided with active experience performing a target action understand a similar observed action as goal directed, whereas infants not given the motor experience do not. Similarly, Daum, Prinz, and Aschersleben (2011) found that the actions 6-month old infants are able to perform covaries with how they interpret others' performance of those actions; specifically, infants who are able to perform a more advanced thumb-opposite grasp are better able to differentiate another person performing a palmar from a thumb-opposite grasp. Sommerville, Hildebrand, and Crane (2008) found that 10-month old infants' previous active experience using a tool to retrieve out of reach objects increased their subsequent understanding of a person using the tool to perform a goal-directed action. Lastly, Sommerville and Woodward (2005) found that 10-month-old infants' ability to solve a means-ends task is predictive of their understanding of another person performing a similar task. Thus, these findings show that infants' understanding of goal-directed actions is facilitated by their own motor experience, sometimes limited to just a few minutes before testing.

As a complement to the preceding studies showing how motor experience facilitates action understanding, Longo and Bertenthal (2006) presented evidence that the actions