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# Six-month-olds actively predict others' goal-directed actions

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ABSTRACT

The current experiment investigated whether 6-month-olds can predict the goal of others' actions. Infants were familiarized to an actor repeatedly reaching for and grasping object-A as opposed to object-B. Object-B was either (1) visible to the actor; (2) hidden by an opaque screen from the actor (but not the infants); or (3) placed behind the screen by the actor herself, so that even though she could no longer see object-B, she was aware of its presence. The positions of the two objects were then reversed. During the test trial, we measured the infants' eye fixations while the actor paused for 6 s. The infants generated predictive eye movements toward object-A only when the actor could see object-B (1) or was aware of its presence in the situation (3). Thus, 6-month-olds can predict, rather than only retrospectively respond to, the goal objects of others' actions.



As adults, we can predict others' actions before they initiate those actions. Various social interactions including driving safely, negotiating job offers, delivering a lecture, and soothing a fussy baby, among others, require our prospective reasoning about others' future actions. Very often, an essential aspect of such reasoning is predicting others' goals. For instance, if you have been observing a toddler repeatedly playing with his ball in a playground and you then see him accidentally throw his ball into the middle of a busy street, you will be alarmed because you will expect him to attempt to get the ball and you will prevent him from running into the street even before he starts to move. The present

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research explores whether 6-month-olds possess the social competence to reason prospectively about others' future actions.

Young infants can detect the goals of others. After watching an actor repeatedly reach for one of two objects, infants looked longer when she reached for a new object rather than the old one (e.g., Luo, 2011; Luo & Baillargeon, 2007; Sommerville, Woodward, & Needham, 2005; Song, Baillargeon, & Fisher, 2014; Woodward, 1998; Woodward & Sommerville, 2000). Infants can even infer the goals of incomplete actions. After observing an uncompleted reaching action, 6-month-olds looked longer when the actor grasped the object she had not previously reached toward (Daum, Prinz, & Aschersleben, 2008). In addition, when an action sequence ended with an unexpected outcome (e.g., the actor holding a spoon in front of his open mouth and then touching his forehead with the spoon), 9-month-olds showed an increased N400 component of an event-related potential (Reid et al., 2009); this is a negative deflection that typically peaks around 400 ms after the onset of an event that does not fit with the previous context (Kutas & Federmeier, 2011).

Infants thus respond to seeing others' goals achieved or nearly achieved, demonstrating that, at a minimum, they make retrospective judgments about the consistency between initial actions and final outcomes. However, we know less about whether infants have the ability to generate on-line predictions about others' goals, a critical aspect of human social competence, which permits us to plan our own actions in a timely and appropriate manner in response to others' actions (e.g., Knudsen & Liszkowski, 2012).

With respect to action sequences, infants do have some ability to make on-line predictions. For example, while watching a human hand repeatedly grasping and moving sets of three toys into a bucket one at a time, 12-month-olds, but not 6-month-olds, moved their eyes to the goal location (the bucket) before the hand actually arrived there (Falck-Ytter, Gredebäck, & von Hofsten, 2006). And even younger infants can make predictions about actions that are familiar to and executable by infants. Kanakogi and Itakura (2011) showed 6-, 8-, and 10-month-old infants a human hand reaching for and grasping one of two objects and found that the infants showed anticipatory eye movements to the goal object before the hand arrived there.

It is possible, however, that the infants in these studies predicted the motion trajectory rather than the actor's goal. In Falck-Ytter et al. (2006), the goal location (the bucket, the only container in the situation) was always placed in the same spot, and thus the path of the hand movement was identical in every trial; infants' proactive eye movements might have reflected the extrapolation of this repeated movement path. In Kanakogi and Itakura (2011), the goal object and the direction of the actor's movement were not the same from trial to trial. However, because their primary measure was the infants' eye movements after the actor started the action, when information about the movement direction was already available, the infants might have anticipated the action based on the initial movement direction rather than the goal.

Some recent findings challenge this possibility. Cannon and Woodward (2012) showed that 11-month-old infants can make goal-based action predictions even when the visible portion of the action is ambiguous. The infants were familiarized with events in which a human hand reached for and grasped one of two toys. Then, the locations of the two toys were reversed. During test, the hand moved forward and stopped between the two toys, an action that did not indicate which of the two toys would be grasped. Infants predictively looked at the goal object for which the hand had repeatedly reached during familiarization.

In addition, previous studies exploiting infants' brain responses suggest that younger infants can predict an action even when information about the actor's movement trajectory is incomplete (Southgate, Johnson, Karoui, & Csibra, 2010; Southgate, Johnson, Osborne, & Csibra, 2009). For instance, when 9-month-olds watched a hand that looked as though it was about to grasp an object (although the object was not visible; the hand disappeared behind an occluder), they showed brain activation related to goal-directed actions, suggesting their prediction of a likely outcome—the grasping of a hidden goal object (Southgate et al., 2010). In contrast, the 9-month-olds did not show such brain responses when there was clearly no object present (the same action was directed toward an empty space without occlusion). Similarly, 9-month-old infants showed motor cortex activity when merely observing a paused scene consisting of an agent and an object for which the agent had repeatedly reached (Southgate & Begus, 2013). Even infants as young as 6 months showed predictive brain