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# Can 14- to 20-month-old children learn that a tool serves multiple purposes? A developmental study on children's action goal prediction

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ABSTRACT

We investigated infants' visual anticipations to the target of an ongoing tool-use action and examined if infants can learn that tools serve multiple functions and can thus be used on different targets. Specifically, we addressed the question at what age children are able to predict the goal of an ongoing tool-use action on the basis of how the actor initiates the action. Fourteen- and 20-month-old children watched a model using a tool to execute two different actions. Each way of grasping and holding the tool was predictive for its use on a particular target. Analyses revealed that the 20- but not the 14-month-olds were able to visually anticipate to the correct target during action observation, which suggests that they perceived the initial part of the tool-use action as predictive for its use on an action target.



## 1. Introduction

Only few non-human species use tools (e.g., de Resende, Ottoni, & Fragaszy, 2008). Yet for humans, their culture and survival appear to be closely linked to their sophisticated use of tools. It has been argued that humans use tools to extend the limits of their own body (Alsberg, 1922). Additionally, researchers have assumed that the ability to develop tools and learn about them by observing other people's tool-use actions is deeply rooted in humans' unique social-cognitive skills, which allow the transmission and accumulation of cultural knowledge (Tomasello, Carpenter, Call, Behne, & Moll, 2005).

While there is disagreement about the evolutionary roots of tool-use (cf. Byrne & Russon, 1998; Csibra & Gergely, 2009; Gehlen, 1940; Tomasello et al., 2005), research has provided substantial evidence that the human ability to use and learn about tools through observation emerges early in development, namely during the first years of life. For example, recent studies on infants' visual expectations show that infants as young as 6 months have acquired rudimentary knowledge about the use of functional objects (Hunnius & Bekkering, 2010; Kochukhova & Gredebäck, 2010; Reid, Csibra, Belsky, & Johnson, 2007) and are able to relate the aperture size of an actor's grasping action to the size of the goal object (Daum, Vuori, Prinz, & Aschersleben, 2009). Whereas this knowledge might provide the basis of early means-end behaviors that can already be observed in the second half of the first year of life (Bates, Carlson-Luden, & Bretherton, 1980; Piaget, 1952; Willatts, 1999), the ability to use tools unfolds largely during the second year of life (e.g., Barrett, Davis, & Needham, 2007; Berger & Adolph, 2003; Connolly & Dalgleish, 1989; Elsner & Pauen, 2007; McCarty, Clifton, & Collard, 2001; van Leeuwen, Smitsman, & van Leeuwen, 1994) and develops further during early childhood (Smitsman & Cox, 2008).

One important aspect of tool-use is that a tool can be used flexibly in different ways to serve different functions and to act on different targets (e.g., German & Defeyter, 2000; German & Johnson, 2002). A claw hammer, for example, can either be used to hit a nail or to remove it. Based on the different action goals, the hammer needs to be grasped and moved differently. As a consequence, the way of acting on the tool (i.e. grasping and holding it differently) becomes predictive for its subsequent use and enables an observer to predict the goal (i.e. target or end location) of an ongoing tool-use action (cf. van Rooij, Haselager, & Bekkering, 2008). Given the importance of tools in daily life and for joint activities in particular, the question arises as to at what age children are able to flexibly predict the goal of an ongoing tool-use action on the basis of how the actor initiates the tool-use action. Interestingly, research on infants' own tool-use abilities has shown that infants' ability to efficiently grasp a tool (i.e., with respect to the goal of the action) improves substantially over the second year of life (e.g., McCarty, Clifton, & Collard, 1999; McCarty et al., 2001).

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McCarty and colleagues (1999) found that in situations in which participants needed to plan their grasping action in advance, only about 30% of the 14-month-old infants, but 85% of the 19-month-old infants were able to grasp the tool with the appropriate radial grip. This finding provides evidence that infants' ability to efficiently plan their grip with respect to the goal of a tool-use actions develops largely between 14 and 19 months of age. Based on findings that infants' action production influences their action perception (Hauf, Aschersleben, & Prinz, 2007; Paulus, Hunnius, Vissers, & Bekkering, in press; Sommerville, Hildebrand, & Crane, 2008; Sommerville & Woodward, 2005; van Elk, van Schie, Hunnius, Vesper, & Bekkering, 2008), we hypothesized that infants' ability to predict the target of an ongoing action by taking into consideration the way a tool is initially being grasped and acted upon should develop between 14- and 20-months of age.

To investigate this hypothesis we employed a predictive looking paradigm. This paradigm is based on findings that infants visually anticipate the target of object-directed actions they observe (Falck-Ytter, Gredebäck, & von Hofsten, 2006; Hunnius & Bekkering, 2010; see also Gredebäck, Johnson, & von Hofsten, 2010). In our study, infants watched a series of short action sequences in which an actor performed two different tool-use actions with the same tool, either using it to insert it into a box or to hit on a bell. The way the model grasped and subsequently held the tool (i.e. which part of the tool was visible) was predictive of its use on one of the two targets. If infants are able to learn to predict the target of the ongoing tool-use action, we expected them to visually anticipate to the correct object on the basis of the model's way of holding the tool.

## 2. Method

### 2.1. Participants

The final sample of the study consisted of 32 infants, including sixteen 14-month-old infants (*range*: 13 months, 15 days to 14 months, 30 days; mean age 423 days; 11 boys) and sixteen 20-month-old infants (*range*: 20 months, 1 day to 21 months, 10 days; mean age 624 days; 7 boys). Five additional 14-month-olds and four additional 20-month-olds were tested but not included in the final sample because of general inactivity, refusal to remain seated, or inattentiveness during the experiment. The participants were recruited from public birth records and were healthy, full-term infants without any pre- or perinatal complications. Informed consent for participation was given by the infants' parents. The families received a baby book or monetary compensation for their visit.

### 2.2. Stimuli

The stimulus material consisted of movies which displayed short action sequences depicting the use of a tool. They showed a frontal view of a male model sitting at a table (see Fig. 1B and C).

The face of the actor was not shown to prevent infants from focusing attention on his face rather than on the ongoing action (cf. Falck-Ytter et al., 2006). Before the actions started, the tool was lying in front of the actor on the table. The tool (see Fig. 1A) was a gray object. It had a long shape (about 18 cm) and consisted of two parts which were of distinct color (light gray and dark gray). The tool was placed in a vertical position to the body of the actor so that one end of the tool was always directed towards him. On the left and right side of the table, there were two target objects on yellow cloths, a bell and a box with a small opening on top.

During the tool-use action sequence, the actor grasped the tool with his right hand at one of its ends and moved his hand with the tool straight away from his body. If the tool was grasped with a full grip at the dark gray end, then the actor always inserted the light gray part into the box and turned it as he would do with a key. If the tool was grasped with a precision grip at the light gray end, the actor brought it to the bell and hit the bell with the dark gray part. No other action combinations of type of grasp, tool-use action, and target object were performed. To draw infants' attention to the action target and not to any acoustical effects of the actions, the stimulus movies were presented without sound. Both action movies had a duration of approximately seven seconds (see Fig. 1B and C for key frames). The movement path which the actor performed with the object consisted of two phases: an ambiguous phase (starting when the model grasped the tool, approximately 3–4 s after stimulus onset) in which the actor's movement was ambiguous with respect to the two possible target objects, as the actor moved his hand along the middle line between both target objects; and the subsequent phase (starting approximately 5–6 s after stimulus onset), during which the actor deviated from the midline and the tool was brought to one of the two target objects. Note that during the ambiguous phase only the way of grasping the tool and the orientation of the tool were predictive of the action's target.

For the action sequences, the part of the tool which was grasped by the actor, the position of the target objects (left or right on the table), and the initial orientation of the tool on the table (which end was pointing to the actor) was counterbalanced. From each of the eight ($2 \times 2 \times 2$) possible combinations two movie versions were made, and thus the stimulus material consisted of 16 action movies.

Piloting with similar stimulus material showed that infants would attend to the tool-use actions for approximately 12 action sequences. Therefore, twelve of the 16 action sequences were composed pseudo-randomly to create movies, which served as stimuli in the experiment. The action sequences were always presented in an ABBABAABABAB order. Note that all trials, in which the target were presented on the same side of the table, were blocked within a movie. Before each block, a still frame (duration 3 s) was presented to allow infants to become familiar with the scene. Eight different versions of these movies were composed out of the action sequences in a way that all conditions (i.e. action sequences) were balanced over all movies. Furthermore, the first two action sequences in every movie showed each of the two actions that could be performed with the tool (see Section 2.4).

### 2.3. Experimental setup and procedure

The infants were seated in an infant seat on the lap of their caregiver. The caregiver sat on a chair that was approximately 60 cm away from the computer monitor. The gaze of both eyes was recorded using a corneal reflection eye-tracker at 50 Hz with an average accuracy of 0.5° visual angle (Tobii 1750, Tobii Technology, Stockholm, Sweden). The stimuli were shown on a 17″ TFT flat-screen monitor. A 9-point calibration procedure with a $3 \times 3$ grid of calibration points was used to calibrate the gaze of each participant before testing. If only seven or less points were calibrated successfully, the calibration of the missing points was repeated; otherwise the experiment was started. First, an attention getter was presented to attract infants' attention to the screen. Then, the experimenter started the experiment with a button press.

### 2.4. Data analysis

We analyzed infants' visual anticipations, i.e. their first eye movement to one of the two target objects during the ambiguous phase of the tool-use action (cf. Falck-Ytter et al., 2006), using a custom-made eye-tracking data analysis software (GSA, Donders Institute for Brain, Cognition and Behaviour, The Netherlands). To