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The roles of observation and manipulation in learning to use a tool

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ABSTRACT

We investigated how repeated, five-minute familiarization sessions occurring once a week over a 6-week period influenced infants' knowledge about the functional properties of a rake-like tool and their ability to use it for retrieving an out of reach object by 16 months of age. We found that infants, who were not allowed to touch the rake, but only to observe an adult retrieve an object with it, improved their performance. On the other hand, infants who were allowed to manually manipulate the rake and touch and move other objects with it did not improve their performance. The results, which were replicated in a string-pulling task, suggest that, although both motor and cognitive limitations affect performance, it is rather cognitive limitations that prevent infants from understanding the functional properties of the tool and from succeeding in such tool-use tasks. Furthermore, infants can overcome these cognitive limitations with only a few, brief demonstrations spaced over several weeks.

1. Introduction

The general definition of tool use is the ability to use one object to extend the boundaries of our physical body in order to act upon another spatially independent object (Beck, 1980). The earliest step toward tool use in development is when infants display means-end behavior to retrieve a distant object that is connected to a within-reach support (Piaget, 1952; Willatts, 1999). When the handle or string is not visibly connected to the desired object, the task becomes more difficult, and infants begin to succeed only during their second year (Leeuwen, Smitsman, & van Leeuwen, 1994; Rat-Fischer, O'Regan, & Fagard, 2012, 2014, see also: Brown, 1990; Chen & Siegler, 2000; Esseily, Nadel, & Fagard, 2010 and Keen, 2011 for similar observations). To explain how infants overcome tool use difficulties, two learning strategies emerge in the literature: observational learning and spontaneous manipulation (Greif & Needham, 2011). We shall first review research supporting one and the other approach, then we continue with the few studies that compared the two.

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1.1. Learning to use tools through observation

Children spend considerable time observing how others interact with objects and readily acquire tool-use knowledge by watching others use tools (Leeuwen, Smitsman, & van Leeuwen, 1994; Want & Harris, 2001; Whiten & Flynn, 2010). Human tools; however, mostly have less evident affordances and possess multiple possible functions. Thus, the causal structure of observable tool use behavior is often inaccessible or cognitively 'opaque' to infants. Gergely Csibra (2005); see also: (Csibra & Gergely, 2009, 2011) proposed that learning through observation and imitation are core components of natural pedagogy, which has evolved as Mother Nature's 'trick' to overcome the difficulties of learning and teaching cognitively 'opaque' cultural knowledge. Their theory of natural pedagogy suggests that children are sensitive to communicative and referential cues from adults that indicate instances of teaching and that by late infancy they observe demonstrations with an assumption that adults provide relevant and new information.

Preschool children are naturally predisposed and motivated to acquire new information and to learn about the causal structure of events (Király, Csibra, & Gergely, 2013). They are known to selectively engage in more exploratory play when the causal structure of events is ambiguous (Schulz & Bonawitz, 2007; Schulz, Gopnik, & Glymour, 2007). This epistemic motivation leads children to not only imitate adult tool use with a high degree of precision (Gardiner, Greif, & Bjorklund, 2011), but also to 'overimitate', that is to faithfully reproduce relevant as well as apparently irrelevant steps of demonstrated action sequences (Horner & Whiten, 2005; Heineman-Pieper, Woodward, Király, & Gergely, 2003; Lyons, Young, & Keil, 2007; Lyons, Damrosch, Lin, Macris, & Keil, 2011; Kenward, 2012). For example, Kenward (2012) shows that preschoolers imitate actions that they already discovered to be unnecessary to achieve an outcome because they consider them as norms.

What prompts children to rely on a demonstrator to learn about the function of a tool rather than relying on themselves? Studies suggest an inverse relationship between the degree of cognitive opacity within the observational learning context and whether children will apply their own understanding of causal relationships and emulate or defer to a demonstrator and learn by observation. For instance, Williamson, Meltzoff, Markman (2008) tested whether prior experience with a task affects learning strategies in 3-year-old children. They found that children who previously failed to use a tool, and thus had difficult prior experience (corresponding to high cognitive opacity), were more likely to imitate the precise tool use of an adult than children who had easy prior experience (low cognitive opacity). In a study by Hopper, Flynn, Wood, and Whiten (2010), preschool children have been found to learn much less about a complex tool-use task when they only saw the parts of the apparatus move 'by themselves' (ghost condition with high cognitive opacity) than when they observed a live demonstrator using the tool, which lead the authors to suggest that for complex or cognitively opaque tasks children require a live model for any form of learning to occur. Finally, in a recent study by Gardiner (2014) cognitive opacity was manipulated by the transparency/opacity of the apparatus itself on which the demonstrator acted. When 3-4-year-olds observed a demonstrator acting on a transparent apparatus and could thus see the physical effects of its moveable parts, they reproduced only the demonstrator's goal and determined the action sequence on their own. Conversely, when the demonstrator acted on an opaque apparatus with causally ambiguous physical structure, the children relied on the demonstration, reproducing the demonstrator's action sequence rather than figuring out the process on their own.

During observational learning of tool use, children also take into account social information, such as the intentions of the demonstrator when selecting which actions to imitate. By 3 years of age, they imitate unnecessary actions when a demonstrator performs them intentionally but not when she performs them accidentally (Carpenter, Akhtar, & Tomasello, 1998; Gardiner, Greif, & Bjorklund, 2011). Thus, understanding the intentions of the demonstrator also reduces the cognitive opacity of tool use situations and helps infants to learn tool use by observation. In a study by Esseily, Rat-Fischer, O'Regan, and Fagard (2013), infants who were shown the intention of the experimenter before the demonstration (she stretched out her arm in an effort to grasp an out-of-reach object) succeeded more in using a rake to retrieve a toy.

1.2. Learning to use tools through manipulation

The second, motor-based approach to tool use is investigated in early studies that describe the changes in motor patterns that characterize, for instance, the development of the use of a spoon (Connolly & Dalgleish, 1989). According to Lockman (2000), "tools alter the properties of effector systems" (p. 137), and early exploration and manipulation is necessary for the infants to gain knowledge about the affordances of their environment.

The idea that motor development influences cognitive development is not new. Piaget described motor skills as a mechanism that drives development in other domains by generating new sensorimotor experiences (Piaget, 1952, 1954). A more recent related idea is Gibson's ecological theory, stating that perceptual experience and cognition are shaped by action execution and are therefore 'embodied' or grounded in the body (Gibson, 1988).

The impact of active experiences on early development has been studied across 'sticky mittens' experiments where infants who could not yet reach for objects themselves were fitted with Velcro-covered mittens allowing the infants to catch toys and move them by merely swiping at them (Needham, Barrett, & Peterman, 2002; Sommerville & Woodward, 2005). These studies showed that training with 'sticky mittens', but not passive reaching experiences (Libertus & Needham, 2010), facilitated exploration behavior and action understanding.

Similarly, in object retrieval tasks, where children rarely succeed before 2–3 years of age in selecting the appropriate tool for retrieving a toy (Brown, 1990; Chen & Siegler, 2000), success increases over trials as children learn about the tools through their own interactive experience with them (Chen & Siegler, 2000).