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The cognitive ontogeny of tool making in children: The role of inhibition and hierarchical structuring

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ABSTRACT

During the last decade, the ontogeny of tool making has received growing attention in the literature on tool-related behaviors. However, the cognitive demands underlying tool making are still not clearly understood. In this cross-sectional study of 52 Turkish preschool children from 3 to 6 years of age, the roles of executive function (response inhibition), ability to form hierarchical representations (hierarchical structuring), and social learning were investigated with the *hook task* previously used with children and animals. In this task, children needed to bend a pipe cleaner to fetch a small bucket with a sticker out of a tall jar. This study replicated earlier findings that preschoolers have great difficulty in tool innovation. However, social learning facilitates tool making, especially after 5 years of age. Capacities to form hierarchical representations and to inhibit prepotent responses were significant positive predictors of tool making after social learning.

Introduction

Making and using tools expertly is considered one of the most distinctive abilities of humans (e.g., Oakley, 1957; Vaesen, 2012) and an area in which humans have become specialized (see Defeyter & German, 2003). However, researchers working on comparative behavioral and brain sciences

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emphasize that many other animals can use tools as well (Meulman, Seed, & Mann, 2013). Nevertheless, human material culture is far richer and human tool-making ability is more flexible as compared with our closest relatives. At this point, understanding the cognitive ontogeny of tool making would help us to better understand what renders our tool-making ability more flexible than that of other animals. In this study, we focused on two cognitive factors that have been highlighted in the literature on the phylogeny and ontogeny of tool-related behaviors: response inhibition (Bjorklund & Harnishfeger, 1995; Bjorklund & Kipp, 2002; Coolidge & Wynn, 2016) and hierarchical structuring (Greenfield, 1991). We claim that tool making requires inhibiting prepotent responses (response inhibition) and connecting information in a hierarchical fashion (hierarchical structuring) and tested this claim in Turkish 3- to 6-year-old preschool children.

From tool use to tool making

Studies show that making more precise plans with tools improves from 9 months to 3 years of age (Bates, Carlson-Luden, & Bretherton, 1980; Brown, 1990; McCarty, Clifton, & Collard, 1999). More recent studies indicate that 20-month-old infants can anticipate the future outcomes of tool use actions (Paulus, Hunnius, & Bekkering, 2011) and that 2-year-old children can use unfamiliar tools in novel problem-solving tasks (Barrett, Davis, & Needham, 2007). Beyond that, 2- to 3.5-year-old children can devise some tool use solutions—which are also observed in apes—without social learning. This observation seems to suggest that great apes' and young children's physical cognition might be similar in this respect (Reindl, Beck, Apperly, & Tennie, 2016). Although using tools for solving simple problems is relatively easy for preschool children, creating novel tools spontaneously—in other words, tool innovation—is challenging for preschoolers (Beck, Apperly, Chappell, Guthrie, & Cutting, 2011).

Cutting, Apperly, and Beck (2011) distinguished two types of tool making: "tool manufacture (the ability to make tools after instruction or observation) and tool innovation (independently making a novel tool to solve a problem)" (p. 497; see also Chappell, Cutting, Apperly, & Beck, 2013). According to Ramsey, Bastian, and van Schaik (2007), "innovation is the process that generates in an individual a novel learned behavior that is not simply a consequence of social learning or environmental induction" (p. 395). Tool innovation is a kind of behavioral innovation in the physical realm (Carr, Kendal, & Flynn, 2016) that requires a new method of tool construction or new ways of using familiar tools for novel problems (Nielsen, Tomaselli, Mushin, & Whiten, 2014).

Beck et al. (2011) demonstrated that until 7 years of age, children have great difficulty in tool innovation in what the authors called the *bending task* (from here onward, the *hook task*) in which children need to bend a pipe cleaner in the form of a hook to retrieve a small bucket inside a transparent vertical tube. However, these children are good at tool manufacture, in other words, tool making by way of social learning mechanisms, specifically tool-making action observation (Cutting et al., 2011). Further studies indicate that their difficulty in tool innovation cannot be explained by the type of the task (Cutting et al., 2011) or by practicing with the tool or not prior to the experiment (Cutting, Apperly, Chappell, & Beck, 2014). Given that preschool children are good at using tools and understanding the function of tools, their great difficulty in tool innovation is unexpected. This might be explained by their inability to produce actions according to their mental simulations and imaginations. For example, Cutting (2013) observed a case where a 3-year-old child gestured a hook shape for the solution of the hook task but did not made a hook shape with the pipe cleaner. This ability to produce actions according to mental simulations spontaneously might improve with age. Considering the rarity of tool innovation before 7 years of age, we focused on social aspects of tool making and its cognitive bases in this study.

Tool-related behaviors and social learning

Social learning and innovations might be the leading engines of our material culture (Carr et al., 2016; Legare & Nielsen, 2015; Lotem, Halpern, Edelman, & Kolodny, 2017). There might be an evolutionary link between brain size and frequency of social learning and innovations (Reader & Laland, 2002). In the hook task, different types of social information might be provided regarding different steps of the tool-making process. Ontogenetic studies with the hook task indicate that different types