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Which way to take? Infants select an efficient path to their goal



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ABSTRACT

In two experiments, we examined the development of the ability to select efficient means in order to attain a goal in 1.5- and 2-year-olds ($N = 79$) using a setup in which two paths led to a goal. One of the paths was shorter, and thus more efficient, than the other path. Experiment 1 showed a strong tendency in both age groups to choose the shorter path. In Experiment 2, the shorter path was initially blocked and became available only after infants repeatedly took the longer path. Children demonstrated increasing use of the more efficient path over time. The results of both experiments point to some abilities of efficient action selection in infants.

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Introduction

A fundamental principle of human action control concerns the tendency to select actions depending on their relative efficiency to reach a goal (e.g., Bernstein, 1967; Rosenbaum, Chapman, Weigelt, Weiss, & van der Wel, 2012). It has been shown, for example, that when rotating an upside-down placed cup, adults start the movement with an uncomfortable thumb-down grip in order to end the movement in a comfortable thumb-up grip (end-state comfort effect; e.g., Short & Cauraugh, 1997; Weigelt, Kunde, & Prinz, 2006). Commonly, such a preference for efficient actions is explained by optimization theory, which assumes that optimal movements will be selected on the basis of their relative costs such as movement time or energy (Jordan, 1996). The ability to choose the most efficient

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action subserves successful action control (Bernstein, 1967) and, from an evolutionary point of view, has supported the evolutionary success of humans and their close relatives (e.g., Weiss, Wark, & Rosenbaum, 2007). Given the relevance of efficient behavior, the question arises of how the ability to consider an action's efficiency develops in early ontogeny.

Interestingly, during the past years an intense debate emerged in the area of early social cognition on whether or not infants already expect other agents to act efficiently. Evidence for this claim has been provided in habituation-based paradigms in which infants' looking times to an agent's efficient and inefficient action choices were assessed (e.g., Biro, Verschoor, & Coenen, 2011; Csibra, 2008; Csibra, Gergely, Biro, Koos, & Brockbank, 1999; Gergely, Nadasdy, Csibra, & Biro, 1995; Scott & Baillargeon, 2013; Sodian, Schoeppner, & Metz, 2004). These habituation-based measures were more recently complemented by studies using imitation paradigms (e.g., Gergely, Bekkering, & Kiraly, 2002) and work relying on eye-tracking measures (Biro, 2013; Elsner, Pfeifer, Parker, & Hauf, 2013; Gredebäck & Melinder, 2010). However, alternative interpretations have been provided in the literature suggesting that these effects could partly be explained by sensorimotor learning (Paulus, Hunnius, & Bekkering, 2013; Paulus, Hunnius, Vissers, & Bekkering, 2011; Paulus et al., 2011; Sirois & Jackson, 2007). For example, Paulus and colleagues (2011) argued that infants' expectations that another agent will take a shorter, and thus more efficient, path to the target (cf. Csibra et al., 1999) might be explained by frequency effects. Infants might more often observe agents to take the most direct path and generalize this expectation to novel situations without having an assumption that the observed agent behaves efficiently. These findings have led to an ongoing debate about the cognitive mechanisms subserving early social cognition (e.g., Paulus, 2012; Skerry, Carey, & Spelke, 2013; Woodward, 2009). Interestingly, they have also revived the debate on whether or not young children's own actions are actually efficient (Klossek & Dickinson, 2012; Paulus & Kiraly, 2013).

Whatever mechanisms underlie these effects, it should be noted that this line of research focused on action interpretation, leaving largely open questions of action control. Yet, it would be important to know whether infants' own action control is actually affected by the relative efficiency of the available means and if they show a stable disposition to choose the more efficient means to attain their goal. What is known in the literature on efficient action control? Here, we briefly review three lines of research.

One line of research focused on rational imitation and over-imitation in young children. Work on so-called rational imitation behaviors has suggested that already infants imitate others' actions depending on the efficiency of the demonstrated behavior (e.g., Gergely et al., 2002; Király, 2009a; Yang, Bushnell, Buchanan, & Sobel, 2013). Yet, this line of research has focused on action interpretation rather than on issues of action control (see Gergely & Csibra, 2003). Moreover, as mentioned above, there has been an ongoing debate in developmental psychology on whether or not these paradigms indeed assess rational behavior or could be explained by other mechanisms (Paulus & Kiraly, 2013). Studies on over-imitation have shown that young children tend to reproduce even unnecessary action steps when imitating a novel action (Lyons, Young, & Keil, 2007). Yet, there is growing evidence that this phenomenon is due to social norm learning (e.g., Kenward, Karlsson, & Persson, 2011) and, thus, is less informative for our research question. Thus, additional evidence from other paradigms seems to be desirable in order to clarify whether infants and toddlers consider actions' relative efficiencies when selecting means to attain a goal target.

Another line of research, which more directly focuses on efficiency considerations in own action control, places the emphasis on planning behavior and the prospective selection of appropriate actions before movement onset (for a review, see McCormack & Atance, 2011). Although some instances of action planning are observable in the tool-use behaviors of 2-year-olds (e.g., Connolly & Dalgleish, 1989; McCarty, Clifton, & Collard, 1999; Piaget, 1953), the cognitive status of these behaviors is unclear because they usually involve highly overlearned and trained objects (e.g., spoons). That is, it remains open whether they are the consequences of trial-and-error learning, observational learning, or even extended training by parents. More directly relevant is research on the ontogeny of the end-state comfort effect (ESCE), that is, the tendency to start actions in an uncomfortable manner in order to end in a comfortable way. In this paradigm, the appropriate action is usually selected before the onset, pointing to the presence of efficiency consideration before action selection. Yet, developmental findings on the ontogeny of the ESCE are quite inconsistent. Some studies reported only little evidence for end-state comfort in preschool children (e.g., Adalbjornsson, Fischman, &

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