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Effects of action on children's and adults' mental imagery

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ABSTRACT

The aim of this study was to investigate whether and which aspects of a concurrent motor activity can facilitate children's and adults' performance in a dynamic imagery task. Children (5-, 7-, and 9-year-olds) and adults were asked to tilt empty glasses, filled with varied amounts of imaginary water, so that the imagined water would reach the rim. Results showed that in a manual tilting task where glasses could be tilted actively with visual feedback, even 5-year-olds performed well. However, in a blind tilting task and in a static judgment task, all age groups showed markedly lower performance. This implies that visual movement information facilitates imagery. In a task where the tilting movement was visible but regulated by means of an on-and-off remote control, a clear age trend was found, indicating that active motor control and motor feedback are particularly important in imagery performance of younger children.

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Introduction

Even though tilting a glass and drinking from it is an everyday action, many children appear to be unaware that the surface of water stays horizontal regardless of the orientation of its container. Piaget and Inhelder (1948/1956) showed this with their classic water level task, a paper-and-pencil task that required children to draw the water level in containers that were presented at different orientations. They concluded that the concept of horizontality is not mastered until 9 or 10 years of age. However,

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replications of this task showed that even adults are far from perfect. College students performed at an error rate of 35% (McAfee & Proffitt, 1991). Waitresses and bartenders, who have a lot of professional experience with filled glasses, showed even worse results (Hecht & Proffitt, 1995). In many studies, males outperformed females (e.g., Liben & Golbeck, 1980; for a meta-analysis, see Kalichman, 1988). After numerous replications, the reasons for these errors are still not clear (for overviews, see Kalichman, 1988; Liben, 1991; Pascual-Leone & Morra, 1991; Vasta, Belongia, & Ribble, 1994). Whereas Piaget and Inhelder's (1948/1956) original interpretation referred to conceptual development, recent explanations include bottom–up mechanisms and propose that errors result from the use of wrong reference systems (e.g., McAfee & Proffitt, 1991), field dependence (Lohaus, Kessler, Thomas, & Gediga, 1994), graphic abilities or graphic tendencies (Gestalt principles) to draw the line perpendicular to the glass (e.g., Liben, 1991; Sommerville & Cox, 1988), and individual differences in perceptual processes and inhibitory skills (Sholl & Liben, 1995).

In another line of research, Schwartz and Black (1999) used a different approach to assess adults' abilities to represent water in tilted containers. Their task required the same basic ability to represent the surface of water as horizontal as in the Piagetian water level task, but it also required the ability to transform mental representations and knowledge about the role of specific stimulus properties such as glass diameter and water level. In this task, adults needed to imagine that two presented glasses of different diameters were filled to the same level with water. When asked which glass would spill first if tilted, participants were usually wrong. However, the study by Schwartz and Black included an additional condition that revealed an important divergence in performance when action plans were involved. When participants were allowed to manually tilt each glass until the imaginary water would reach the rim, they correctly tilted a narrow glass farther than a wide one. This research showed that adults are able to imagine the transformation of the water inside a container and to simulate the tilting movement with their hands without having explicit knowledge about the correct answer and how it is affected by glass diameter and water level.

This finding raises a series of important questions about the sources of information people are using to achieve correct performance and the age at which the ability to use these sources emerges. In the current study, we used a tilting task based on the Schwartz and Black (1999) task to investigate children's abilities to transform mental representations of water inside a container and, more specifically, how manual movement facilitates these mental transformations.

Motor feedback in perception and imagery

It is undisputed that action plans, mental models, cognitive maps, and other internal representations guide our actions. However, the extent to which our actions may influence our internal representations is less evident. Several studies with adult participants suggest that motor activities may feed back on cognitive processes such as perspective taking (Simons & Wang, 1998; Wang & Simons, 1999) and mental rotation (Schwartz & Holton, 2000; Wexler, Kosslyn, & Berthoz, 1998; Wohlschläger & Wohlschläger, 1998). The notion that action plays a central role in cognition has recently attained high visibility under the label of *embodied cognition* (for an overview, see Overton, 2008; Wilson, 2002). Theories of embodied cognition emphasize the importance of sensory and motor functions for cognition and for a successful interaction with the environment. For example, it is argued that embodiment processes underlying infants' early understanding of and interaction with their physical and social environments might still account for a significant proportion of the same skills in adults (Daum, Sommerville, & Prinz, in press). Based on behavioral, neurophysiological, and brain imaging data, it has been proposed that planned actions and perceived events share a common representational domain (Prinz, 1997) or that observed and executed actions activate the same neuronal regions in the brain, the so-called mirror neuron system (for a review see Rizzolatti & Craighero, 2004). Such a close link between action and perception is thought to be especially important in action understanding and imitational learning. The assumption of direct feedback from motor activities to higher cognitive processes might explain how people can predict the consequences of their actions or coordinate their mental representations with their actions (Creem, Wraga, & Proffitt, 2001).