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## Preschool children adapt grasping movements to upcoming object manipulations: Evidence from a dial rotation task

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### ABSTRACT

In adults, the motor plans for object-directed grasping movements reflects the anticipated requirements of intended future object manipulations. This prospective mode of planning has been termed second-order planning. Surprisingly, second-order planning is thought to be fully developed only by 10 years of age, when children master seemingly more complex motor skills. In this study, we tested the hypothesis that already 5- and 6-year-old children consistently use second-order planning but that this ability does not become apparent in tasks that are traditionally used to probe it. We asked 5- and 6-year-olds and adults to grasp and rotate a circular dial in a clockwise or counterclockwise direction. Although children's grasp selections were less consistent on an intra- and inter-individual level than adults' grasp selections, all children adjusted their grasps to the upcoming dial rotations. By contrast, in an also administered bar rotation task, only a subset of children adjusted their grasps to different bar rotations, thereby replicating previous results. The results indicate that 5- and 6-year-olds consistently use second-order planning in a dial rotation task, although this ability does not become apparent in bar rotation tasks.

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## Introduction

Every day, we interact and manipulate objects in our environment. Although such activities appear rather mundane, we exhibit considerable sophistication in planning and controlling these movements. Important in the current context, when someone grasps an object, the grasping act not only is determined by the characteristics of the object but already is adjusted to the requirements of planned subsequent actions. For example, the orientation of a grasp is adapted to a subsequent rotation of the grasped object, thereby enabling further, faster, and more accurate rotations (Coelho, Studenka, & Rosenbaum, 2014; Herbort, 2015; Short & Cauraugh, 1999; for a review, see Rosenbaum, Chapman, Weigelt, Weiss, & van der Wel, 2012).

The ability to adapt grasping movements to intended object manipulations has been termed *second-order planning* (in contrast to first-order planning, which reflects only immediately perceivable constraints such as object shape or position; see Rosenbaum et al., 2012; Rosenbaum, Herbort, van der Wel, & Weiss, 2014). This ability is usually examined with tasks that require grasping and manipulating objects. A classic example is the so-called *bar transport task* (Rosenbaum et al., 1990). In this task, a horizontal bar on two stands needs to be grasped and placed vertically on its left or right end. Right-handed adults usually grasp the bar with an overhand grip (forearm prone) for placing the bar on its right end and with an underhand grip (forearm supine) for placing it on its left end. Left-handed grasps show the reverse pattern. Importantly, in all cases the initial grasp enables placing down the object in a comfortable end posture. Hence, the finding is termed the *end-state comfort effect* (Rosenbaum et al., 2012).

### *Development of second-order planning*

Surprisingly, it takes until about 10 years of age for children to start showing adult-like second-order planning in the bar transport task (Jovanovic & Schwarzer, 2011; Stöckel & Hughes, 2015; Stöckel, Hughes, & Schack, 2012; Thibaut & Toussaint, 2010; Weigelt & Schack, 2010; Wunsch, Pfister, Henning, Aschersleben, & Weigelt, 2016; for a review, see Wunsch, Henning, Aschersleben, & Weigelt, 2013). Similar results have been reported for other tasks such as rotating overturned glasses, using a spoon, hammering a peg, inserting swords into holes, and rotating fixed dowels and knobs (Comalli et al., 2016; Fuelscher, Williams, Wilmut, Enticott, & Hyde, 2016; Scharoun & Bryden, 2014; Smyth & Mason, 1997; van Swieten et al., 2010; Wilmut & Byrne, 2014b; Wunsch et al., 2016). Moreover, attempts to make the end-state of the object manipulation more salient did not alter grasp selections much (Knudsen, Henning, Wunsch, Weigelt, & Aschersleben, 2012; Manoel & Moreira, 2005; Thibaut & Toussaint, 2010).

The discrepancy in grasp selection between adults (e.g., Coelho et al., 2014; Comalli et al., 2016; Rosenbaum et al., 1990) and children, who adjust their grasps consistently to upcoming tasks, seems to be based on two aspects. First, only a subset of children show signs of second-order planning; typically, only 60% to 80% of 5-year-olds show the end-state comfort effect in the majority of trials (e.g., Hughes, 1996; Knudsen et al., 2012; Weigelt & Schack, 2010; Wunsch et al., 2016). Thibaut and Toussaint (2010) reported that 50% of 4-year-olds and 23% of 6-year-olds showed the end-state comfort effect in 20% of the trials or less. Some children did not adjust their grasps to the upcoming tasks in a single trial (24–40% of 4-year-olds in Comalli et al., 2016; 11% of 4-year-olds in Keen, Lee, & Adolph, 2014; 25% of 6-year-olds in Stöckel & Hughes, 2015). Second, children who show the end-state comfort effect do so less consistently than adults, often with considerable variability between children (Comalli et al., 2016; Keen et al., 2014).

In the current study, we focused on the first aspect. The differences between children's and adults' grasp selection may be explained in various ways. First, a subset of preschool children may simply not have second-order planning abilities. Second, preschool children may have the ability for second-order planning but still plan their grasps with respect to other criteria than adults (cf. van Swieten et al., 2010), are less efficient than adults (Fuelscher et al., 2016; Stöckel et al., 2012), or might not always be able to implement second-order planning (Comalli et al., 2016; Keen et al., 2014; Wunsch & Weigelt, 2016).

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