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The development of the grasp height effect as a measure of efficient action planning in children

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One effect that illustrates how people adjust aspects of their grasping according to situational constraints is the grasp height effect; when reaching for objects positioned at different heights, adults' grasp height (vertical position of the hand on the object) tends to correlate negatively with object height. This indicates that grasp positions are planned so that they facilitate later placements of the object. The current study investigated the development of the grasp height effect with 3-year-old children, 5-year-old children, and adults. This paradigm allows for studying efficient action planning in the context of a simple task with relatively low motor requirements. Other tasks used so far for studying this issue involved relatively complex adjustments of hand position that younger children might have found difficult to perform. Usually, preschoolers' performance on these tasks was relatively low. We expected that, due to the lower motor requirements of the grasp height paradigm, clearer evidence of efficient planning might be found in preschool children. A second focus of this study was to explore children's behavior in different movement phases of the grasping task. Whereas the task of placing an object at different heights involves planning, putting the object back to its original position seems to depend on recall. The results indicate a significant grasp height effect in all age groups but also significant development across the studied age range. Regarding the second movement phase, when participants were required to put the objects back on the original home shelf, 3- and 5-year-olds did not seem to act based on recall in this context.

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Introduction

Usually, we take for granted the ease with which we perform our daily routines, as, for example, grasping a mug. We are mostly unaware of the multitude of degrees of freedom with which different tasks can be accomplished. Thus, we could grasp the mug at different positions across its surface by using different grasp configurations. However, normally, we use only a specific subset of grasps out of the many possible. One reason for this is that, from a motor planning perspective, some grasps are more efficient than others in terms of the achievement of a superordinate goal or the coordination of an action sequence. If we were to drink from the mug subsequently, it would be more efficient to grasp it by its handle than by its rim. The current study focused on the development of this kind of efficient planning, which has also been termed "second-order planning" (Rosenbaum, Chapman, Weigelt, Weiss, & van der Wel, 2012).

One example of efficiency-related second-order planning is the end-state comfort effect (e.g., Rosenbaum et al., 1990). This term refers to the finding that when grasping objects, adults tend to ensure a comfortable posture at the end position of the movement at the cost of starting the movement with an uncomfortable hand orientation. This has been assumed to serve the function of maximizing motor control at movement endpoints; by avoiding extreme joint angles at the end of a movement, individuals can improve the precision of subsequent manipulations. In the classic bar transport paradigm introduced by Rosenbaum and colleagues (1990), participants were given the task of placing a horizontal bar into a vertical position, with one of the ends pointing up. They produced a consistent pattern of grasp choices depending on the initial orientation of the bar and the required end position; initial grasps varied in terms of underhand (palm turned up) or overhand (palm turned down) grasp orientation, so that they always resulted in a comfortable end position of the hand with the thumb pointing upward. This effect illustrates how adults consistently, and apparently effortlessly, adapt their actions to specific task demands.

During childhood, planning efficient grasps is an ability that comes online quite early but then takes quite a long time to reach levels of adult performance. As an example, McCarty, Clifton, and Collard (1999) observed children learning to eat with spoons. They arranged the spoons so that on half of the trials the spoons could be grasped properly only by using the non-preferred hand. The 9-month-olds' behavior corresponded to a trial-and-error strategy, whereas by 19 months of age children were able to adapt to the initial orientation of the spoon by grasping flexibly with either their preferred or non-preferred hand.

In contrast, children do not fare so well in the classical end-state comfort paradigm. Here, there has been a huge variance in findings regarding the age of onset. Whereas some studies using the original bar transport task found very low performance in participants under 6 years of age (Adalbjornsson, Fischman, & Rudisill, 2008; Knudsen, Henning, Wunsch, Weigelt, & Aschersleben, 2012; Manoel & Moreira, 2005; Thibaut & Toussaint, 2010), more recent studies suggest a gradual improvement across ages, beginning by around 3 years of age (Jovanovic & Schwarzer, 2011; Weigelt & Schack, 2010). To add to the complexity of the findings, studies investigating the handle rotation task, an end-state comfort paradigm requiring participants to rotate a handle clockwise or counterclockwise toward a visually specified target, speak in favor of an even more protracted development, with even 9- to 14-year-old children lagging significantly behind adults in their performance (van Swieten et al., 2010; Wilmut & Byrne, 2014).

The evidence so far allows no definitive conclusion concerning the factors influencing the age effects on task performance. However, several have been proposed to account for the differences in findings. First of all, task-related factors concerning procedural differences between the tasks employed have been discussed; as an example, the required precision of the task is one classical factor affecting performance in adults, with higher precision demands resulting in higher rates of end-state comfort planning (Short & Cauraugh, 1999). Furthermore, the familiarity with the object used has been found to modulate performance (Knudsen et al., 2012) and child-related factors regarding children's developing skills and capacities, for example, motor imagery (Toussaint, Tahej, Thibaut, Possamai, & Badets, 2013). Correspondingly, for some age groups, a correlation between end-state