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Development of planning in 4- to 10-year-old children: Reducing inhibitory demands does not improve performance

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A B S T R A C T

Currently, there are relatively few tasks suitable for testing planned problem solving in children. We presented 4- to 10-year-old children ($N = 172$) with two planning tasks (sequential planning and advance planning) using the paddle-box apparatus, which was originally designed to investigate the planning skills of nonhuman apes. First, we were interested in the development of children's performance in the two tasks and whether the strategies children used to succeed differed among age groups. Performance improved significantly across age groups in both tasks. Strategies for success in the advance planning task differed among age groups, with 4- and 5-year-olds performing more excess actions, and a greater proportion of irrelevant excess actions, than older children. Findings are discussed in relation to the development of performance in tower tasks, which are a commonly used test of planning ability in humans. Second, based on previous findings with apes, we predicted that introducing measures to reduce the inhibitory demands of the advance planning task would improve children's performance. Therefore, in this study we introduced two methodological alterations that have been shown to improve children's performance in other tasks with inhibitory demands: (a) imposing a short delay before a child is allowed to act and (b) replacing reward items with symbolic tokens. Surprisingly,

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neither of these measures improved the performance of children in any of the age groups, suggesting that, contrary to our prediction, inhibitory control might not be a key performance-limiting factor in the advance planning paddle-box task.

Introduction

Planned behavior involves considering different sequences of action alternatives and choosing between them prior to acting (McCormack & Atance, 2011). It is a complex cognitive process, the development of which occurs in conjunction with and is supported by various key executive function processes. Executive functions are a group of skills necessary for the control of thought and action required for reasoning, planning, and problem solving (Anderson, 1998; Baughman & Cooper, 2007). Key executive functions include inhibitory control, working memory, and task switching (Asato, Sweeney, & Luna, 2006; Baughman & Cooper, 2007; McCormack & Atance, 2011). Given that there are currently few appropriate tasks for investigating planned problem solving in young children (McCormack & Atance, 2011), this study used a novel paradigm originally designed for testing nonhuman apes (hereafter apes) to present two planning tasks to children and explored whether inhibitory control might be a key performance-limiting factor.

Development of planned problem solving

Tower tasks, such as the Tower of London (ToL; Shallice, 1982), are the most commonly used test of planning ability in humans (McCormack & Atance, 2011), although other experimental studies of planning in children have used route planning tasks (e.g., Gauvain & Rogoff, 1989) and "real-world" scenarios (e.g., Hudson & Fivush, 1991). In the ToL task, participants are presented with two sets of three pegs (start and goal), with three different-colored discs arranged on each set. The aim of each trial is to rearrange the discs on the start pegs so that they match the configuration of discs on the goal pegs. Problem complexity can be manipulated by increasing the number of moves required to solve the trial as well as by altering structural features of the problem such as the number of intermediate moves (i.e., where a disc must be moved into a temporary position that is not its final goal position) a participant is required to make (Kaller, Rahm, Köstering, & Unterrainer, 2011). The planning demands of the task stem from the need to anticipate the consequences of one's next actions (McCormack & Atance, 2011). Efficient performance involves mental representation of the path from the start state to the goal state, followed by behavioral reproduction of the action sequence (Albert & Steinberg, 2011).

Several studies have examined the development of ToL performance across different age groups. Luciana and Nelson (1998) found that 4-year-old children performed poorly in 3-step ToL trials compared with 2-step trials. Asato and coworkers (2006) investigated the development of performance in 2- to 5-step ToL problems in 8- to 30-year-olds. Age effects were found only for the more complex 4- and 5-step problems. As age increased, the number of excess moves being made decreased (Asato et al., 2006). Finally, in a study of 10- to 30-year-olds, Albert and Steinberg (2011) found that performance in 3-step ToL trials was not mature until 16 or 17 years of age.

Work by Kaller and colleagues (Kaller, Rahm, Spreer, Mader, & Unterrainer, 2008; Kaller et al., 2011) demonstrates the significant impact that structural details of seemingly comparable ToL trials (rather than just the number of steps) can have on performance. For example, Kaller and colleagues (2008) showed that although 4-year-olds were able to solve 3-step trials that did not require an intermediate move, they struggled when an intermediate move formed part of the solution despite being instructed to plan their moves before starting. The authors suggested that the key difference between these two types of 3-step trial was that whereas trials without intermediate moves could be solved