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Time monitoring and executive functioning in children and adults

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Abstract

This study examined time-based prospective memory performance in relation to individual and developmental differences in executive functioning. School-age children and young adults completed six experimental tasks that tapped three basic components of executive functioning: inhibition, updating, and mental shifting. Monitoring performance was examined in a time-based prospective memory task in which participants indicated the passing of time every 5 min while watching a movie. Separate analyses of the executive functioning data yielded a two-factor solution for both age groups, with the updating and inhibition tasks constituting a common factor and the shifting tasks constituting a separate factor. Both children and adults showed accelerating monitoring functions with low rates of clock checking during the early phase of each 5-min interval. However, compared with adults, children needed more clock checks for obtaining the same level of response accuracy. Executive functioning had selective effects on time-based prospective memory performance. In both children and adults, monitoring performance was related to the inhibition and updating components, but not to the shifting component, of executive functioning. We conclude that difficulties in temporary maintenance and updating of working memory contents may create discontinuities in sense of time, leading to an increased reliance on external cues for time keeping.

Keywords: Executive functioning; Time monitoring; Prospective memory; Updating; Inhibition; Mental shifting; School-age children; Young adults

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Introduction

Most goal-directed activities require temporal integration and monitoring of action sequences (Fuster, 1993, 2002; Luria, 1966; Norman & Shallice, 1986). In general terms, monitoring is the process by which agents assess their environments and involves activities such as assessing the progress of initiated plans, finding out what time it is, and anticipating obstacles. For example, remembering to complete an action in the future involves a monitoring phase during which the individual must monitor for the appropriate cue to execute an action. However, most everyday activities involve multiple goal-directed tasks, and efficient monitoring requires a strategy, or a scheme, for scheduling actions (i.e., when and how to monitor). In most situations, this strategy must balance the cost of monitoring against the cost of having inaccurate information about the environment, and deciding between these costs can be a complicated optimization problem (Atkin & Cohen, 1996).

Although monitoring is a necessary task for all agents, including children, insects, and robots, few studies have investigated how these agents actually behave when the goal or deadline is approaching. Yet the monitoring concept has connections to several areas, including operant conditioning (Ferster & Skinner, 1957), process control (Moray, 1986; Senders, 1983), and some areas of ethology (for a review, see Pyke, 1984). However, research on time-based prospective memory suggests certain regularities of monitoring behavior in children and adults (Ceci & Bronfenbrenner, 1985; Harris & Wilkins, 1982; for an overview, see Mäntylä & Carelli, 2006).

Ceci and Bronfenbrenner (1985) conducted a seminal study of time-based prospective memory in school-age children. In their study, 10- and 14-year-olds were instructed to remove cupcakes from an oven in exactly 30 min to avoid burning them. In another condition, the children charged a battery and were instructed to turn the charger off after 30 min to prevent overcharging. During the 30-min interval, the children played a video game in a separate room (either at home or in a laboratory setting). The clock was placed behind the children, so that the experimenter (siblings) could easily see when the children turned around to determine how much cooking or charging time remained. This checking was associated with a cost because the act of monitoring was a distraction from the game.

Ceci and Bronfenbrenner (1985; see also Ceci, Baker, & Bronfenbrenner, 1988) found that all children checked the clock frequently during the first 10 min of the waiting period and then engaged in very little clock checking until the final moments of the waiting period. Specifically, older children in both settings and younger children in the home setting reduced the frequency of monitoring actions during the middle period, from 10 to 25 min, of the task interval. When younger children were tested in the unfamiliar laboratory setting (and with an unknown experimenter), they maintained the frequency of clock checking at the same high level also during the middle phase of the task.

This study and other studies (Cicogna, Nigro, Occhionero, & Ésposito, 2005; Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995; Kerns, 2000; Maylor, Smith, DellaSala, & Logie, 2002; Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997; see also Mäntylä & Carelli, 2006) suggest regularities in monitoring behavior. However, mechanisms underlying time monitoring and their relation to response accuracy (i.e., time-based prospective memory performance) are less well understood.

According to one view of prospective memory, an executive attentional system explicitly monitors the environment for target events. Following this view, retrieval occurs