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Brief Report

Working memory in children: A time-constrained functioning similar to adults

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ABSTRACT

Within the time-based resource-sharing (TBRS) model, we tested a new conception of the relationships between processing and storage in which the core mechanisms of working memory (WM) are time constrained. However, our previous studies were restricted to adults. The current study aimed at demonstrating that these mechanisms are present and functional before adulthood. For this purpose, we investigated the effect on maintenance of the duration of the attentional capture induced by processing. In two experiments using computer-paced WM span tasks, 10-year-olds were asked to maintain letters while performing spatial location judgments. The duration of this processing was manipulated by varying either the discriminability between target locations or the contrast between targets and background. In both experiments, longer processing times resulted in poorer recall, as we observed previously in adults. These findings suggest that the core mechanisms of WM described by the TBRS model are already settled during childhood.

Introduction

Working memory (WM) is a capacity-limited cognitive system devoted to the simultaneous maintenance and processing of information that plays a crucial role in complex cognitive activities as well as in many elementary ones (Barrouillet, Lépine, & Camos, 2008; Camos, 2008; Camos & Barrouillet, 2004; Kyllonen & Christal, 1990). It has often been argued that most of the differences in cognition

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between children and adults are due to children's limitations in WM capacity (Case, 1985; Halford, 1993; Pascual-Leone, 1970). We recently proposed a new model of WM named the time-based resource-sharing (TBRS) model that puts forward a new conception of the relationships between processing and storage in which the core mechanisms are time constrained (Barrouillet, Bernardin, & Camos, 2004; Barrouillet & Camos, 2007). We verified the main assumptions of this model in adults (Barrouillet, Bernardin, Portrat, Vergauwe, & Camos, 2007; Barrouillet et al., 2004), but it remains undetermined whether WM functioning presents the same characteristics and constraints in children. Thus, the current study addressed this question by testing in children the specific predictions of our model concerning the effect of time on WM.

The TBRS model is based on four main proposals. First, the two main functions of WM, which are the processing and maintenance of information, rely on the same limited attentional resource. Second, a bottleneck constrains central processes, allowing only one attention-demanding cognitive step to take place at a time. This sequential functioning of WM means that when attention is occupied by some processing episode, it is not available for the maintenance of memory items. Third, as soon as attention is switched away from maintenance to processing, the activation of the memory items suffers from a time-related decay and their memory traces fade away. Thus, a refreshment of these items is needed before their complete disappearance through reactivation by attentional focusing. Fourth, this sharing of attention is achieved through a rapid and incessant switching of attention from processing to maintenance occurring during short pauses that would be freed while concurrent processing is running. Following these assumptions, when the time allowed to perform the processing component of a WM span task is kept constant, any increase in the duration of the attentional capture this processing involves extends the period during which memory traces fade away, thereby resulting in a greater memory loss. This model leads to a new metric of the cognitive load involved by a given task as the proportion of time during which this task occupies attention.

To test these assumptions, we elaborated a new paradigm of computer-paced WM tasks that permits a careful control of time parameters. In these tasks, participants are presented with items to be recalled, for example, letters. After each letter, they need to perform an intervening task divided into atomic steps, with the duration of this task being controlled. In many experiments, we demonstrated that any increase in the cognitive load induced by this intervening task has a detrimental effect on concurrent maintenance and recall. For example, increasing the number of atomic steps, such as reading digits within a fixed time interval or reducing the time allowed to perform a fixed number of processing steps, resulted in poorer recall (Barrouillet et al., 2004). The most striking test of the TBRS model was to verify that a mere increase in the duration of each atomic processing step results in a memory loss even if the number and nature of processing steps, as well as the total time allowed to perform them, are kept constant. For this purpose, Barrouillet and colleagues (2007) used a task in which each letter was followed by eight stimuli consisting in a black square centered on one of two possible locations in either the upper or lower part of the screen. Adult participants were asked to judge the location of each square as quickly as possible by pressing appropriate keys. According to the TBRS model, longer response selections should be more disruptive on concurrent maintenance of information because they involve a longer occupation of the central bottleneck impeding other attention-demanding processes such as refreshment activities to take place. We manipulated the duration of the response selections by varying the distance between the two possible locations (either 5 or 68 mm apart). As we surmised, the close condition drastically diminished the targets' discriminability and induced longer responses than did the distant condition (377 and 314 ms, respectively). As the TBRS model predicted, the longer attentional capture induced by the close condition had a detrimental effect on maintenance and resulted in poorer recall performance than did the distant condition (mean spans of 5.51 and 5.81, respectively). This finding lent strong support to the TBRS model by suggesting that longer processing episodes involve longer attentional capture, impeding the switching toward decaying memory traces and their refreshment.

However, Towse and Hitch (2006) cogently noted that the findings supporting the TBRS model are restricted to adults and that it is not clear that our interpretation would necessarily apply to children. We must admit that this remark is quite sound. Although we have studied children's WM, we never specifically tested in children the central assumption of the TBRS model concerning time-related effects. Barrouillet and Camos (2001) observed in 9- and 11-year-olds that increasing the difficulty of