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Children's use of semantic organizational strategies is mediated by working memory capacity

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ABSTRACT

In adults, the ability to apply semantic grouping strategies has been found to depend on working memory. To investigate this relation in children, two sort-recall tasks (one without and one with a grouping instruction) were administered to 6–12-year-olds. The role of working memory was examined by means of mediation analyses and by assessing whether children who successfully used the semantic grouping strategy had higher working memory capacity than did children who did not show such strategy use. Only children aged 8–12 were able to successfully use semantic grouping strategies (and 8–9-year-olds only after instruction), while strategy use was absent in 6–7-year-olds. Both types of analysis involving working memory suggested that, also in children, working memory (and not short-term memory) mediates the development of successful use of the semantic grouping strategy during both encoding and retrieval.

Storage of information in long-term memory (LTM) can be improved by the use of strategies that organize information in working memory (WM) prior to encoding. Storage of information in meaningful groups facilitates later retrieval (Dehn, 2008; Shiffrin & Atkinson, 1969; Tulving, 1962). Such groupings may be based on perceptual similarities between items, such as a similar color or shape, or on semantic relatedness, such as belonging to the semantic category "animals" (Lange, Guttentag, & Nida, 1990; Melkman, Tversky, & Baratz, 1981). Effective employment of grouping strategies aids children both in daily activities and in academic contexts. For example, children's organization of basic

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math facts in LTM helps them to recall those facts later to solve larger, more complex mathematical problems (Geary & Brown, 1991). Learning-disabled children have been reported to make less use of semantic organizational strategies in a free-recall task and show poorer recall (Bauer, 1977; Torgesen, 1977).

It is thus important to identify the factors involved in children's ability to apply intentional grouping strategies. The present study examines the role of age and conditions and, in particular, the role of working memory capacity (WMC). By about age 7, children begin to use elementary memory strategies, such as rehearsal (Ornstein, Baker-Ward, & Naus, 1988; Ornstein & Naus, 1978). Preschoolers spontaneously group material based on overlap in perceptual features but not on semantic relationships (Melkman et al., 1981). When items have strong, well-learned semantic associations (e.g., cow–milk), grouping strategies are reported to emerge relatively early, at around age 9. However, when items have low within-category associations (e.g., bird–dolphin), spontaneous application of the semantic grouping strategy is only reported beginning at age 13 (Bjorklund & de Marchena, 1984; Bjorklund & Jacobs, 1985).

Such developmental differences can be explained by differing demands on mental resources. When associations are well-learned, they are activated more or less automatically when seeing or hearing stimuli, requiring no active-grouping strategy (Schneider & Pressley, 1997). When associations between stimuli are less well-learned, one must actively search for and encode such relationships in WM (Baddeley, 2000; Daneman & Carpenter, 1980). Because WM has limited capacity and is subject to development, WM may affect children's ability to actively apply semantic memory-grouping strategies. Late development of this ability (Bjorklund & de Marchena, 1984; Bjorklund & Jacobs, 1985) parallels the recently reported prolonged maturational course of WM into adolescence (Conklin, Luciana, Hooper, & Yarger, 2007; Diamond, Kirkham, & Amso, 2002; Schleepen & Jonkman, 2010). The neurobiological source of this late development has been identified as the protracted development of a network of prefrontal and parietal brain regions that undergo considerable structural and functional changes throughout this period (Bunge & Wright, 2007; Luna, Padmanabhan, & O'Hearn, 2010). Furthermore, WM plays an important role in learning complex cognitive activities involving language, mathematics, and reasoning (Andersson & Lyxell, 2007; Barrouillet & Lepine, 2005; Noel, 2009; Pickering, 2006), perhaps involving strategy use.

A link between WM and the productive application of grouping strategies has been shown in adults. Individuals with high WM span are more likely than those with a low span to employ a semantic clustering strategy when retrieving information from LTM in a verbal fluency task (Rosen & Engle, 1997), and those with more effective semantic memory strategies show superior WM (McNamara and Scott (2001).

To our knowledge, only two studies have explored relations between WM and semantic grouping in children. Developmental studies have often made use of "sort-recall" tasks (Schneider & Pressley, 1997) that typically consists of two phases. In the first phase, children are presented with randomly ordered pictures of objects that belong to different semantic or perceptual categories. They are instructed to study these pictures for later recall and told they may move the pictures if they think it will help them remember. After a short "buffer-clearing" interval, in a second phase children are asked to verbally report as many pictures as they can. The level of grouping on perceptual or semantic relatedness a child engages in is evaluated by computing so-called clustering scores (Roenker, Thompson, & Brown, 1971).

Using a sort-recall task, Schneider, Kron, Hunnerkopf and Krajewski (2004) studied differences in WM among school-aged children who were consistently strategic or utilization deficient (UD) in the use of the semantic-grouping strategy. Children were assessed at two time points and classified as UD if their sorting behavior increased significantly across time without corresponding increases in recall. Consistent strategy users were those children who applied the sorting strategy at both points and demonstrated consistently high recall. UD children had lower WM scores (measured by the digit span backward task) than consistent strategy users. In a follow-up study including nine longitudinal measurement points, Kron-Sperl, Schneider, and Hasselhorn (2008) reported that individual differences in short-term memory (STM) span, but not WMC, predicted recall performance in 8–10-year-olds who spontaneously used the semantic grouping strategy. There are, however, several factors that might explain the absence of a WM-semantic memory grouping relation in this study. The to-be-grouped