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Working memory and recollection contribute to academic achievement

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ABSTRACT

The contributions of working memory and recollection to academic achievement are typically examined separately and most often with children who have learning difficulties. This study is the first to observe both types of memory in the same study and in typically developing children. Academic achievement focused on standardized assessments of math fluency, calculation, reading fluency, and passage comprehension. As noted in previous studies, working memory was associated with each assessed measure of academic achievement. Recollection, however, specifically contributed to math fluency and passage comprehension. Thus, recollection should be considered alongside working memory in studies of academic achievement.

1. Introduction

There are wide ranging individual differences in children's academic achievement. Variations in reading and math performance between children with and without learning difficulties are quite apparent to classroom teachers and parents alike. Even in typically developing children with no learning difficulties, individual differences in reading and math performance can be readily observed (e.g. Hecht, Torgesen, Wagner, & Rashotte, 2001, Jenkins, Ruchs, van den Broek, Espin, & Deno, 2003). Researchers have reported various distal contributors to these performance level differences (e.g., family socio-economic status, Aikens & Barbarin, 2008; parental interaction style, Mattanah, Pratt, Cowan, & Cowan, 2005; classroom instruction technique, Kilbanoff, Levine, Huttenlocher, Vasilyeva, & Hedges, 2006). More proximal contributors (e.g., working memory, Gathercole, Alloway, Willis, & Adams, 2006; Swanson, Jerman, & Zheng, 2008) have also been the focus of attention and with good reason. Academic-based processes rely on the formation and use of representations, a complex process that requires many cognitive skills, including memory.

A comprehensive connection between memory and academic skills is lacking because of the literature's focus on contributions from a single cognitive process, such as working memory (e.g., Daneman & Hannon, 2001) or components from a single process, such as the factors that make up working memory (e.g., Nevo & Breznitz, 2011). The ability to comprehend and produce representations requires many mechanisms (Paivio, 1990); thus, there is a need to examine multiple cognitive processes and how they differentially contribute to academic achievement. The purpose of our study was to examine contributions of two different memory processes (recollection and working memory) to performance on standardized measures of academic achievement in children. Other studies tend to examine executive memory in relation to academic achievement; we took a more comprehensive view of memory in our study.

Associations between working memory (WM) and numerous aspects of learning and academic achievement in children are well established (e.g., Bourke & Adams, 2003; Bull, Johnson, & Roy, 1999; Gathercole, Brown, & Pickering, 2003; Nevo & Breznitz, 2011; Stevenson, Bergweriff, Heiser, & Resing, 2014; Swanson, 1993, 1994). WM is a complex cognitive process consisting of several components (Baddeley, 1992) that differ in their contributions to complex reading and math abilities (Nevo & Breznitz, 2011). One of the WM components, the episodic buffer, integrates information for short and long term memory use (Baddeley & Wilson, 2002). The episodic buffer allows for short term binding of contextual and item information that is later consolidated, allowing for the formation of episodic memories (EM) (Tulving, 1972). Because of these associations between WM and EM, we examined the contributions of both types of memory processes to academic achievement in math and reading. In the following paragraphs we highlight literature relating WM and EM to academic achievement. We then explain how the episodic buffer is connected to EM and we link EM with academic achievement.

1.1. Working memory: development and academic achievement

WM is the ability to simultaneously maintain and manipulate information (Baddeley, 1992). WM capacity increases throughout childhood and into adolescence (for review see Gathercole, Pickering, Ambridge,

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and Wearing (2004)). Substantial improvements in WM during middle childhood may be attributed to the emergence of successful rehearsal techniques (Hulme, Thomson, Muir, & Lawrence, 1984) and increased processing speed (Cowan et al., 1998) found during this period.

WM contributes to reading achievement in children (for a meta analysis see Carretti, Borella, Cornoldi, and De Beni (2009)) because it aids in the conceptualization of words and the ability to maintain the words online for comprehension (Baddeley, 2003; Siegel, 1994). Thus, WM is related to skills necessary for reading fluency and comprehension, such as production of grammatical fluency (Ellis, 1996), syntactic comprehension (Santi & Grodzinsky, 2007), and phonological processing (Da Fontoura & Siegel, 1995). This has led to training programs designed to enhance WM. For example, preschool aged children have shown improvements in WM after training (Holmes, Gathercole, & Dunning, 2009). WM training with older children (9–11) has resulted in improvements in reading performance (Loosli, Buschkuehl, & Perrig, 2012).

In addition to benefits associated with achievements in reading, WM performance has been connected to benefits in mathematics (for review see Raghubar, Barnes, and Hecht (2010)). Specifically, WM is associated with the ability to retrieve arithmetic facts from LTM (Kaufmann, 2002) and maintain numerical representations (Geary, 1993). These relations also explain why WM plays a crucial role in the ability to calculate and solve math-based word problems (Logie, Gilhooly, & Wynn, 1994; Swanson & Beebe-Frankenberger, 2004). In sum, the literature connecting WM to academic achievement is well developed.

1.2. Episodic memory: development and academic achievement

EM refers to memory for specific items and their contextual information (Tulving, 1972) and is often discussed in the adult cognition literature from a dual-process prospective, separating EM into recollection and familiarity (Yonelinas, 2002). Recollection refers to the detail-rich memory for items and contextual information. Recollection is typically what is brought to mind when we think of EM and the process of retrieving information from our past. To elaborate, recognizing an object is not sufficient to require recollection; we must retrieve details regarding other contextual factors of the information. Familiarity is a global evaluation of memory strength. Research with adults supports the notion that recollection and familiarity are dissociable processes (Diana, Yonelinas, & Ranganath, 2007).

Very young children's recollection is far less complex or detailed than that of adults. This is likely due to the lack of experience recollecting past events and continuation of neural development (Ghetti & Lee, 2013; Riggins, 2012). Familiarity, however, appears to remain stable by age six (Ghetti & Angelini, 2008). The literature also suggests that familiarity develops far earlier than recollection. A study exploring recollection and familiarity in 8–19 year olds found that while familiarity remained constant with age, recollection increased with age (Billingsley, Smith, & McAndrews, 2002), suggesting that recollection continues to develop into adolescence. Ghetti and Angelini (2008) found similar results in 6–18 year olds using confidence ratings and receiver operating curves (i.e., plotted hits in relation to false alarms as confidence changed).

In a rare study of academic achievement examining the EM dichotomy of recollection and familiarity, Mirandola, Del Prete, Ghetti, and Cornoldi (2011) reported on adolescents with and without reading difficulties, Adolescents with learning difficulties displayed a deficit in recollection, but not familiarity, suggesting that only recollection was associated with academic success in reading. We are aware of no studies exploring this dichotomy in relation to math achievement. Associations between recollection and math have been found through use of recall tasks (e.g. Fletcher, 1985, Stevenson & Newman, 1986). Recall tasks elicit recollection processes, especially if recall of contextual information is required (Yonelinas, 1994; Yonelinas, 2002). However, the studies focused on recollection did not consider other critical contributors to reading or math achievement, such as WM.

By examining the unique contributions of WM and recollection, we can broaden our understanding of cognitive contributors to academic achievement. Increasing our understanding of how childhood memory operates could have practical implications in educational settings. Our study focused on WM and the recollection aspect of EM during middle childhood.

1.3. Episodic buffer and episodic memory

As previously noted, one of the components of the WM model is the episodic buffer (Baddeley, 2000). This element allows for information to be integrated across time and space, allowing for short term binding of contextual and item information. The episodic buffer is further believed to aid in the sending and receiving of information from EM (Baddeley, 2000). The other elements of WM, visuospatial sketchpad and phonological loop, are thought to aid in visual and verbal semantics, respectively. In a study exploring these aspects of WM, all three components were correlated with reading achievement (Nevo & Breznitz, 2011), suggesting that each WM component also associated with EM plays a role in reading achievement. It may be, however, that EM and WM contribute uniquely to academic achievement. This idea is supported by brain imagining evidence suggesting that the prefrontal cortex is associated with WM (Curtis & D'Esposito, 2003), whereas the medial temporal lobe, specifically the hippocampus, is associated with EM (Squire & Cave, 1991). As the literature currently stands, it could be argued that relations between EM and academic achievement are actually attributed to WM because of the episodic buffer's role in EM. And indeed, EM and WM are correlated (Schneider & Weinert, 1995). We propose, however, that recollection plays an independent role in academic achievement because of the separate neural process associated with EM and WM.

1.4. Current study

We took a comprehensive view of memory by examining the unique contributions of WM and recollection (i.e., an aspect of EM) to reading and math achievement. As we have noted, most research examining recollection is focused on children with learning difficulties (Mirandola et al., 2011; Spring & Capps, 1974; Swanson, 1994; Weekes, Hamilton, Oakhill, & Holliday, 2008). A good deal of the literature examining WM contributions to academic achievement likewise focuses on school-aged children with learning difficulties (e.g. Carretti et al., 2009; Raghubar et al., 2010). Understanding how WM and recollection processes contribute to the reading and math performance of typically developing children without reading or math difficulties is critical for a more complete picture of individual differences in academic achievement.

Therefore, we examined the contributions of two memory processes to achievement in typically developing children. We hypothesized that WM and recollection would statistically predict reading and math achievement, as assessed by standardized tests. In our analyses, we simultaneously examined potential contributions of WM and recollection to account for unique variance associated with each memory process.

2. Method

2.1. Participants

Our sample comprised 81 children (52% female; 9–11 years, $M = 10.38$, $SD = .73$) who made up one cohort from an on-going longitudinal study on cognition and emotion development. Some children had been participating since infancy (n = 57) and others were newly recruited for this visit (n = 24). Children were predominantly Caucasian (89%) with highly educated parents; 99% of mothers and 91% of fathers had at least some education beyond high school. As compensation for participation, parents received a $50 gift certificate and children received a small gift and a $10 gift certificate.