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Exploring Working Memory Deficits in Academic Learning: Strategies for Identification and Intervention

Antigoni Premeti [1], Eleni Lekka[2], Georgios Pilafas[2,3], Penelope Louka[2,4,5]

[1] Psychology Student, University of Derby (UK) at Mediterranean College campus, Athens, Greece
[2]Accredited Lecturer, University of Derby (UK) at Mediterranean College campus, Athens, Greece
[3]Programme Leader 'BSc (Hons) Applied Psychology', University of Derby (UK) at Mediterranean College campus, Athens, Greece
[4]Head of School of Psychology, Mediterranean College, Athens, Greece
[5]Deputy Head of Academic Affairs (Learning, Teaching & Assessment), Mediterranean College, Athens, Greece

Corresponding Author: Antigoni Premeti

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ABSTRACT

This article investigates the critical role of working memory (WM) in academic learning and the challenges faced by children with WM deficits. Drawing on a comprehensive review of existing literature, the study examines the prevalence of educational difficulties among school-age children and elucidates the intricate relationship between WM deficiencies and various cognitive processes. Through a systematic analysis of empirical evidence, the article delineates two primary approaches to addressing WM deficits: managing WM loads in instructional settings and direct WM enhancement through targeted interventions. Strategies for alleviating WM burdens in classrooms, such as simplifying instructions and task structures, are examined in depth. Furthermore, the study explores the efficacy of WM training programs, including computer-based interventions like Cogmed Working Memory Training, in bolstering WM capacities and scholastic performance. The essay critically evaluates the concept of neuroplasticity and its implications for WM training, highlighting challenges in achieving transfer effects across cognitive domains. It concludes by advocating for a multifaceted approach to remediation, emphasizing the integration of diverse educational strategies, including computerized training and classroom-based interventions, to effectively support children grappling with WM deficits in their academic pursuits.

Keywords: Working Memory Deficit; School-Age Children; Memory Training Programmes; Neuroplasticity; Educational Psychology

INTRODUCTION

Low educational achievements of school-age children have been the center of attention for many researchers over the last years (Gathercole et al., 2006). In the US and the UK, 14% to 30% of school-age children require extra help with their learning (Department for Education, 2018; National Center for Education Statistics, 2019). According to Catts et al. (2012), 16% of students have reading challenges, and 7% of students are dyslexic (Peterson & Pennington, 2012). Furthermore, 3% of kids struggle with comprehension (Lervåg & Aukrust, 2010). Developmental language impairments affect about 10% of children

(Laasonen et al., 2018), while 3% to 13% of youngsters struggle with math (Geary, 2013). Children often struggle with a variety of behavioral and learning issues. In children with mathematical learning challenges, simultaneous reading difficulties are seen in 17% to 70% of cases, whereas in children with reading problems, the rates of mathematics difficulties range from 11% to 56% (Dirks et al., 2008). Learning disabled people face long-term repercussions such as early school disengagement (Balfanz et al., 2007), low employment rates (De Beer et al., 2014), and increased risk of behavioral and mental health problems (Emerson & Hatton, 2007). Working memory (WM) is a cognitive system that seems to have a crucial role in academic learning. Due to its predictive capabilities, it has been suggested to play a fundamental role in various cognitive activities within the school environment (Gathercole et al., 2004). Working memory is the term employed to describe a system responsible for temporarily storing and manipulating information (Gathercole et al., 2006). It acts as a mental workspace, adaptable for supporting various cognitive activities that involve both processing and storage, such as mental arithmetic. Nevertheless, the capacity of WM is restricted, and introducing excessive demands for either storage or processing during an ongoing cognitive task can result in a significant loss of information from this temporary memory system (Gathercole et al., 2006). Working memory undergoes its most significant development during the initial 10 years of life, surpassing any other stage throughout the rest of the lifespan (Alloway & Alloway, 2014). It typically reaches adult capacity levels around the age of 14 years (Gathercole et al., 2004). During typical development, children exhibit substantial increases in their WM capacity (Pickering, 2001). However, there are instances where the anticipated development of certain aspects of working memory appears to be either delayed or disrupted in some children. WM is essential for various daily tasks, including reading and learning new skills, as well as being a fundamental component of many cognitive processes (Henry, 2012). It is closely associated with attention, language acquisition (Weiland et al., 2014), mental arithmetic (Cragg et al., 2017), reading development (Kudo et al., 2015), and sensory and motor skills (Leonard et al., 2015). As a result, a deficiency in working memory is linked to a broad spectrum of learning challenges, including specific language impairment (Archibald & Gathercole, 2007), dyslexia, and reading difficulties (Jeffries & Everatt, 2004), as well as dyscalculia and mathematical learning issues (Szucs et al., 2013). Children with inadequate WM skills face difficulties in various classroom activities, such as recalling and executing instructions, problem-solving, and planning and organizing tasks (Alloway et al., 2009). Teachers commonly describe such children as inattentive and easily distracted (Alloway et al., 2009). Children struggling with poor working memory find it challenging to handle the cognitive demands of the classroom, leading to issues in completing learning activities. This ongoing challenge contributes to subpar educational progress, with accumulating problems affecting performance across different classroom tasks. Evidence suggests that children who score poorly on WM tests between the ages of 7 and 14 also typically perform below expectations in English, mathematics, and science national curriculum assessments (Gathercole et al., 2004). Consequently, working memory stands out as one of the most reliable predictors of a child's academic achievement (Alloway & Alloway, 2014; Alloway et al., 2009).

Though there are numerous WM models, a widely accepted model (Baddeley, 2000; Baddeley & Hitch, 1974) suggests that working memory comprises four components. At its core is a central executive system, a domain-general limited capacity system often compared to a mechanism for attentional control. The central executive is supported by two domain-specific storage components: the phonological loop and the visuo-spatial sketchpad. Each of these elements can be broken down into two fundamental subcomponents: a store with limited capacity, holding only a small number of items and experiencing rapid decay unless refreshed by the second subcomponent, which is a rehearsal process (Baddeley, 1986). Phonological loop is responsible for auditory information and has been associated with the capacity to acquire new knowledge and skills, especially in the context of reading and language development. Children who experience specific reading difficulties exhibit deficiencies in various phonological skills, such as nonword reading, phonological awareness, and rapid naming (Kudo et al., 2015). Visuo-spatial sketchpad specializes in processing visual and spatial information and is closely related to mathematical abilities. It acts as a mental blackboard, aiding in tasks related to number representation, such as understanding place value and alignment in columns during counting and arithmetic (McLean & Hitch, 1999). Children with deficient visuo-spatial memory skills may face limitations in their mental blackboard capacity, making it harder to retain relevant numerical information (Heathcote, 1994). Baddeley (2000) also identified the episodic buffer as an additional subcomponent of working memory, tasked with integrating information from the working memory subcomponents and long-term memory.

Despite the above-mentioned evidence that link WM deficits with poor academic performance, WM is not a firmly established concept in education, and most teachers have not undergone training neither on identifying WM issues in the classroom nor on effectively supporting students with such challenges in their learning (Gathercole et al., 2006). In order to maximize students learning, research has focused on various methods to overcome working memory deficits. Starting with identification of the issue, The Working Memory Rating Scale (WMRS) is an extensively used scale, designed to evaluate working memory deficits in a classroom setting (Alloway et al., 2008). This questionnaire concentrates exclusively on working memory-related issues within a single scale. It can be quickly administered and scored without the need for prior training in psychometric assessment. Alloway et al., (2009) presented preliminary data on the reliability and criterion validity of the WMRS based on their normative sample, which included 417 children aged five to eleven from England. Their initial results indicated excellent internal consistency of the WMRS factor, with a Cronbach's alpha of .978. Regarding working memory interventions, working memory was formerly thought to be genetically fixed (Kremen et al., 2007), meaning that an individual's experiences or opportunities in the environment couldn't change it. However, a rising collection of research undermines this assumption, indicating remarkable cerebral flexibility throughout the developing brain. By using this strategy, environmental support and intervention may be able to increase working memory capacity (Buschkuehl et al., 2012). These findings underscore crucial possibilities for enhancing the learning, behavioural, and social outcomes for the substantial number of children facing working memory challenges.

In general, there are 2 main approaches to support children with WM deficits. The first is to reduce failures in the classroom by efficiently managing working memory loads. According to Alloway & Gathercole, (2006) to address this, teachers could provide concise and straightforward directions, simplify words, and offer memory aids in the form of number lines and helpful spellings. To elaborate on this approach, many times, children with low WM may forget their next tasks, leading to difficulties in completing various learning activities. Improving children's memory for instructions involves making instructions as brief and simple as possible, breaking them down into individual steps whenever feasible (Alloway & Gathercole, 2006). Frequent repetition of instructions is an effective strategy for enhancing the child's memory for the task. For tasks spanning an extended period, reminding the child of crucial information for that specific phase rather than repeating the original instruction tends to be more helpful. Asking the child to repeat crucial information is one of the most effective ways to ensure they haven't forgotten important details (Alloway & Gathercole, 2006). In addition, to manage WM loads, Alloway & Gathercole, (2006) proposed methods that involve reduce working memory demands and minimizing task failures in activities that engage the child in processing and storing information. For instance, they observed that sentence writing posed a particular challenge for children with low working memory. To address this, processing demands can be lessened by reducing the linguistic complexity of the sentence. This objective can be realized using various strategies, such as simplifying language, choosing common words over uncommon ones, and simplifying sentence structure. Encouraging the utilization of straightforward constructions like active subject-verb-object forms, as opposed to sentences with intricate clausal structures, is also advised (Alloway & Gathercole, 2006). Additionally, sentences can be shortened. A child who struggles with working memory, engaging in tasks involving concise sentences, straightforward vocabulary, and uncomplicated syntactic structures, is more apt to retain the sentence structure in working memory and make a successful attempt at writing (Alloway & Gathercole, 2006).

The second approach involves directly enhancing working memory. WM performance can be improved by receiving training in working memory and executive tasks, according to a number of research (Gathercole et al., 2019). Giving participants instruction on memory techniques is one way to provide working memory training. The application of strategies, which are deliberate, cognitively taxing procedures used to improve memory performance, leads to developmental gains in WM (Gathercole et al., 2019). Several research studies have indicated improvements in tasks related to short-term memory when participants apply strategies like rehearsal (Rodriguez & Sadoski, 2000), visual imagery (De la Iglesia et al., 2005), crafting narratives from information to be remembered (McNamara & Scott, 2001), or grouping items into conceptual categories. An approach to provide training in memory strategies involves utilizing computer-based instruction and practice. For instance, children's adventure game Memory Booster (Leedale et al., 2004) is entertaining. Using memory techniques like visual imagery, storytelling, rehearsing, and grouping are all taught and encouraged by this game. Simply repeating verbal information is known as rehearsal; visual imagery is the process of forming mental images to help retain the information; storytelling is the process of creating a narrative that connects the information; and grouping is the process of organizing items into higher-order conceptual categories, like "living things." Research conducted on small groups of six- to seven-year-old children revealed that Memory Booster significantly improved working memory assessments (St Clair-Thompson & Holmes, 2008). Currently, there is a variety of working memory training programs available. Some of these programs replicate working memory tests, requiring individuals to process and store information for short durations. Examples include remembering numbers in backward order or recalling shape locations on a grid (Alloway et al., 2013). Others involve tasks where individuals need to update information and maintain it in their minds for brief periods, such as the n-back task (Alloway et al., 2013). Another training is the Cogmed Working Memory Training (CWMT) which involves intensive practice on a series of computer-based memory tasks over 20–25 sessions. To make sure people are working to their own limits, the degree of difficulty for every task is continuously changed (Klingberg et al., 2002). Following CWMT, improvements in working memory have been noted in a number of populations, including children in preschool and primary school who are typically developing (Holmes et al., 2012a). Cogmed training significantly enhances memory performance in kids with WM deficiencies, bringing it up to age-appropriate levels. These improvements last for a minimum of half a year following the end of the training program (Dunning et al., 2012). Evidence of accelerated learning following training has also been observed; children with working memory problems reported notable gains in their mathematics scores several months after the instruction (Holmes et al., 2009). Although these results suggest that memory enhancements may enhance learning capacity, they have only been confirmed in closely watched trials. It might not be feasible to duplicate the training provided in these studies in non-research contexts because it is carried out by seasoned researchers under ideal, frequently resource-intensive circumstances. Consequently, these studies do not provide definitive proof of the advantages of training in the context of real-world application (Holmes & Gathercole, 2013). To address these challenges and bring WM from the laboratory to schools, Holmes & Gathercole, (2013) in their study, presented findings from two field trials where teachers administered training to their pupils. In Trial 1, a class of 8–9-year-old children underwent training, assessing their performance on various memory tasks before and after. The trial aimed to determine if teacher-led training resulted in a similar pattern of improvement as researcher-led training. In Trial 2, teacher-led training impact on end-of-year school assessments was assessed for children with poor academic performance, investigating whether it was associated with academic improvement. National achievement tests, used for monitoring school progress and identifying underachieving students, provided educationally relevant performance measures (Holmes & Gathercole, 2013). The results of their study showed that, after training in Trial 1, children showed notable enhancements in both trained and untrained working memory tasks, with effect sizes akin to those seen in research studies. In Trial 2, improvements on the trained tasks were similar, and the training correlated with significantly increased progress in school, particularly in math and English, throughout the academic year. These results suggest that training administered by teachers leads to widespread and substantial improvements in working memory, coupled with educationally meaningful advancements in academic performance (Holmes & Gathercole, 2013).

Through extensive practice, performance on the majority of trained tasks tends to improve, and these gains are reflected in alterations to the underlying brain systems. This type of learning is commonly referred to as neuroplasticity (Gathercole et al., 2019). The transfer of working memory gains observed after adaptive training is believed to be associated with cortical plasticity within the neural system supporting WM. This concept suggests lasting changes in areas related to WM, comparable to the effects of perceptual training on the visual cortex. Proposed mechanisms include potential alterations in individual neuron response characteristics and improvements to white matter tracts' structure (Gathercole et al., 2019). While there is supporting evidence for neural changes resulting from various training activities, the concept faces challenges in explaining the limited benefits observed for everyday cognitive functions widely considered to rely on WM (Gathercole et al., 2019). Even within WM tasks such as n-back and complex span, transfer remains minimal, as indicated by a recent meta-analysis (Soveri et al., 2017). This suggests that the neuroplasticity concept may not fully account for the complexities of WM transfer effects. WM training may not uniformly expand overall capacity but could enhance specific processes in particular tasks, addressing the lack of transfer across WM paradigms (Soveri et al., 2017). This suggests that training focuses on updating, inhibitory function, and short-term memory storage within WM, applicable to some but not all WM tasks (Minear et al., 2016). Transfer occurs when both training and transfer tasks demand the same processes. Participants in training studies often employ mnemonic strategies (Minear et al., 2016), potentially contributing to training-induced changes. However, strategy transfer is limited by how stimuli in untrained tasks can be represented. For instance, digit span training demonstrated content-specificity in mnemonic strategies, with recoding digit sequences expanding digit span but leaving memory span for letter sequences unchanged (Chase & Ericsson, 1981). Similar findings emerged from a study of adults trained on digit span for four months (Martin & Fernberger, 1929). Strategies may have limited value even when stimuli are the same but the WM tasks change, as shown in participants undergoing spatial n-back or verbal complex span training, who reported different strategies despite both tasks involving letters as memoranda (Minear et al., 2016).

Working memory impairments are strongly linked to learning deficits and impact daily classroom activities. If not addressed early, these memory deficits cannot be compensated for over time, posing a persistent threat to a child's academic success (Alloway, 2006). Thus, applying the most promising WM intervention is crucial in the context of education. Techniques related to effective management of working memory loads are simple and easy to use by teachers in the classroom. However, they have short-term results as they are not as intense as working memory trainings who challenge more the brain of the students (St Clair-Thompson et al., 2010). Teaching memory strategies can be especially advantageous for young children because they typically do not naturally use such strategies. For instance, rehearsal, a common memory strategy, typically emerges around the age of seven (Gathercole, 1998), while other strategies develop later (Bjorkland & Douglas, 1997). Children will, however, attempt to employ strategies if given clear instructions (Ornstein et al., 1988). For this reason, teaching kids' memory techniques may improve their recall skills. It may be beneficial for educators to use Memory Booster in the classroom to improve students' performance. According to Aunola et al. (2002), this strategy might break the pattern of kids with low working memory experiencing repeated learning setbacks, which might affect their drive to learn. Teachers can use Memory Booster with ease because it doesn't require a lot of instructor input-entire classes can utilize it. In order to provide the right amount of challenge and optimize learning outcomes, the program dynamically modifies task complexity based on a child's progress. Combining computerized strategy training, such as Memory Booster, with other remediation methods, including managing working memory loads in the classroom, could be particularly effective (Gathercole & Alloway, 2008).

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