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Research Paper

Crossing the bridge to elementary school: The development of children's working memory components in relation to teacher-student relationships and academic achievement

Loren Vandenbroucke[a,*], Karine Verschueren[b], Annemie Desoete[c], Pirjo Aunio[d], Pol Ghesquière[a], Dieter Baeyens[a]

[a] Parenting and Special Education, KU Leuven – University of Leuven, Belgium
[b] School Psychology and Child and Adolescent Development, KU Leuven – University of Leuven, Belgium
[c] Experimental Clinical and Health Psychology, University of Gent, Belgium
[d] Special Educational Needs, University of Helsinki, Finland

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ABSTRACT

Working memory is important for a variety of life domains, including for children's school functioning. As such, it is crucial to understand its development, antecedents and consequences. The current study investigates the development of different working memory components (phonological loop, visuospatial sketchpad, central executive), the influence of different aspects of the teacher-student relationship (closeness, conflict, dependency) and its predictive value for academic achievement (reading, spelling, mathematics) across the transition from kindergarten to first grade. The sample consisted of 107 kindergarten children. Working memory tasks were administered at the end of kindergarten and first grade. Teachers reported on teacher-student relationship quality in the middle of first grade. Standardized tests were used to assess academic achievement at the end of first grade. Results indicate moderate to large increases in the phonological loop and visuospatial sketchpad and large gains in the central executive. Dependency of the student towards the teacher significantly predicted visuospatial sketchpad performance at the end of first grade. Reading was significantly predicted by the visuospatial sketchpad and phonological loop in kindergarten, while for spelling the visuospatial sketchpad was important. Finally, mathematics was predicted by performance on the phonological loop and the visuospatial sketchpad. The current study indicates the importance of the affective quality of the teacher-student relationship for working memory performance, which in turn is important for academic achievement. It is therefore critical to attend to the early detection and prevention or intervention of working memory problems in the classroom in order to prevent future academic problems. Additionally, maintaining a positive relationship with students and encouraging their independent exploration may be important when preventing such problems, complementary to cognitive or other types of training and intervention.

1. Introduction

For children's school functioning, working memory is of utmost importance. Children use their working memory throughout the day in the classroom, both in showing positive behavior (e.g., positive work habits and engagement in learning; Brock, Rimm-Kaufman, Nathanson, & Grimm, 2009) and during academic tasks (e.g., Alloway & Alloway, 2010). Because of the importance of working memory for outcomes in the classroom, understanding its development, antecedents and consequences can help to prevent a wide range of educational problems. Recent research shows that factors in the classroom environment, such as the teacher-student relationship, influence the performance on working memory tasks (e.g., de Wilde, Koot, & van Lier, 2015).

However, empirical research examining the role of the teacher-student relationship in working memory and the role of working memory for academic achievement is scarce. Moreover, previous studies do not always distinguish between the different working memory components, limiting our insights into their relationships with different aspects of the teacher-student relationship and academic achievement.

* Corresponding author at: Leopold Vanderkelenstraat 32, 3000 Leuven, Belgium.
E-mail addresses: Loren.vandenbroucke@kuleuven.be (L. Vandenbroucke), Karine.verschueren@kuleuven.be (K. Verschueren), Annemie.Desoete@UGent.be (A. Desoete), Pirjo.aunio@helsinki.fi (P. Aunio), Pol.ghesquiere@kuleuven.be (P. Ghesquière), Dieter.baeyens@kuleuven.be (D. Baeyens).

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Therefore, the current study aims to investigate these relationships during children's transition from kindergarten to first grade, an important period in the development of working memory.

1.1. Executive functions and working memory

Executive functions are cognitive processes that are essential in making goal-directed behavior possible (Diamond, 2013; Zelazo & Carlson, 2012). There are three core executive functions: working memory, inhibition and cognitive flexibility. Working memory is an executive function that starts to develop early in life and is important for various outcomes across the lifespan (e.g., mental and physical health; Diamond, 2013). This memory system is responsible for holding information in mind, including new information (updating) and mentally manipulating this information. We use working memory, for example, to calculate, to find out the meaning of written information, to execute complex instructions or to combine multiple sources of information before making a decision.

Baddeley (1986) conceptualized working memory as a multicomponent system. His model distinguishes two slave systems, the phonological loop and the visuospatial sketchpad. The phonological loop can temporarily store verbal information and rehearse this information or update it with new information in order to support recall of the information (Baddeley, 1986; Gathercole, Pickering, Ambridge, & Wearing, 2004). The visuospatial sketchpad can temporarily hold information with a visual or spatial nature (Baddeley, 1986; Gathercole et al., 2004). Both these components are controlled by the a third aspect of working memory, the central executive. In this component information is not merely stored, both actively processed and manipulated (Baddeley, 1986; Gathercole et al., 2004). This system is used, for example, when making a calculation: the numbers and operators need to be remembered and the information needs to be manipulated when making the calculation. Later, Baddeley added a fourth component, the episodic buffer, that integrates information of different memory systems into episodic representations (Baddeley, 2000). However, due to the lack of reliable measures for this component in young children, the current study will make use of the three component model (De Pontes Nobre et al., 2013).

In very young children (age 4) the central executive and phonological loop have been found to be distinguishable (Alloway, Gathercole, Willis, & Adams, 2004). From the age of 6 the three factor model provides the best fit (Gathercole et al., 2004). At this age the phonological loop and visuospatial sketchpad show a relatively strong relationship with the central executive (r = 0.73-0.85; Gathercole et al., 2004).

The development of working memory depends (in part) on the maturation of the prefrontal cortex (Anderson, 2002). Working memory abilities start to develop early in life (Diamond, 2013; Reznick et al., 2004), show important developmental spurts during preschool and the early years of formal schooling (ages 3–8; Ganea & Harris, 2013; Hongwanishkul, Happaney, Lee, & Zelazo, 2005; Kibbe & Leslie, 2013; Moher & Feigenson, 2013) and continue to develop gradually at least until adolescence (Conklin, Luciana, Hooper, & Yarger, 2007; Gathercole et al., 2004). Different components of working memory show different developmental trajectories. For example, the central executive starts to develop later than the two slave systems (Davidson, Amso, Anderson, & Diamond, 2006; Garon, Bryson, & Smith, 2008), suggesting it is likely to show rapid improvements around the time of transition to first grade. In first grade, the classroom environment becomes more complex and greater demands are placed on children's working memory (e.g., more complex instructions; Cuevas, Hubble, & Bell, 2012; Hughes, Ensor, Wilson, & Graham, 2010; Roebers, Röthlisberger, Cimeli, & Michel, 2011). Such changes can influence the development of working memory, for example by challenging children's working memory abilities, giving this development an additional boost (Roebers et al., 2011). Despite the importance of this transition, the number of studies examining working memory development specifically at this point in time are limited.

1.2. Working memory and the teacher-Student relationship

Although the development of working memory is largely driven by the maturation of the prefrontal cortex, this maturation occurs in interaction with environmental stimulation in periods of rapid development (Huttenlocher, 2002). When children enter formal schooling, the classroom context becomes an important part of children's environment in which stimulation can be provided. A high-quality teacher-student relationship, characterized by high closeness, low conflict and low dependency, has previously been shown to have a positive effect on several aspects of children's development, including social development, cognitive functioning and academic performance (Downer, Sabol, & Hamre, 2010; Verschueren & Koomen, 2012).

The attachment perspective, often employed in teacher-child relationship research, can explain how aspects of the teacher-student relationship can affect working memory (Roorda, Koomen, Spilt, & Oort, 2011; Verschueren & Koomen, 2012). According to this view, children who have a positive affective relationship with their teacher (e.g., high closeness, low conflict, low dependency) use the teacher as a secure base from which to explore the school environment (Roorda et al., 2011). As such, children with a positive teacher-child relationship will engage more in stimulating learning activities, which is likely to promote the development of the prefrontal cortex and aspects of working memory. Additionally, children who view the teacher as a safe haven will return to the teacher when distressed, leading to more optimal stress regulation (Roorda et al., 2011). A study of Ahnert, Harwardt-Heinecke, Kappler, Eckstein-Madry and Milatz (2012) indeed shows that children sharing a positive relationship with their teacher show more optimal patterns of stress regulation. In turn, stress has been found to negatively affect the development and functioning of the prefrontal cortex, executive functioning and working memory (Diamond, 2013; Hughes, 2011; Kolb et al., 2012). The three different components of working memory can each be influenced by a positive teacher-child relationship. Rapidly developing components, such as the central executive around the transition to first grade, are more likely to be influenced, as their underlying brain regions undergo large changes and are most sensitive to environmental stimulation (Huttenlocher, 2002).

A recent study of de Wilde et al. (2015) found a bidirectional relationship between child-perceived teacher-child relationship quality and children's performance on a task measuring the central executive at the age of 5–8. Cross-lagged models show that especially conflict in the relationship seemed detrimental, while warmth between the teacher and the student had a modest positive effect. Similarly, Hamre, Hatfield, Pianta and Jamil (2014) found a positive relationship between observed sensitive teaching and classroom organization with the central executive component of working memory at the age of 4. Both a positive classroom climate and positive affective relationships between the teacher and specific students can thus promote working memory. Hence, the first results of studies examining the relationship between teacher-student interactions and working memory are assuring, though studies are still scarce and focus mainly on the central executive. It is therefore unclear how the teacher-student relationship relates to the different subcomponents of working memory.

1.3. Working memory and school functioning

Understanding the development of working memory is important as good working memory abilities relate to positive outcomes in a number of domains, such as children's school functioning (Diamond, 2013). Previous research has shown a positive relationship between working memory abilities and academic achievement in school aged children after controlling for children's fluid and crystallized intelligence (e.g., Alloway & Alloway, 2010; Desoete & De Weerdt, 2013; De Weerdt,