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The importance of working memory for school achievement in primary school children with intellectual or learning disabilities

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ABSTRACT

Background: Given the well-known relation between intelligence and school achievement we expect children with normal intelligence to perform well at school and those with intelligence deficits to meet learning problems. But, contrary to these expectations, some children do not perform according to these predictions: children with normal intelligence but sub-average school achievement and children with lower intelligence but average success at school. Yet, it is an open question how the unexpected failure or success can be explained.
Aims: This study examined the role of working memory sensu Baddeley (1986) for school achievement, especially for unexpected failure or success.
Method and procedures: An extensive working memory battery with a total of 14 tasks for the phonological loop, the visual-spatial sketchpad and central executive skills was presented in individual sessions to four groups of children differing in IQ (normal vs. low) and school success (good vs. poor).
Outcomes and results: Results reveal that children with sub-average school achievement showed deficits in working memory functioning, irrespective of intelligence. By contrast, children with regular school achievement did not show deficits in working memory, again irrespective of intelligence.
Conclusions and implications: Therefore working memory should be considered an important predictor of academic success that can lead both to unexpected overachievement and failure at school. Individual working memory competencies should be taken into account with regard to diagnosis and intervention for children with learning problems.

1. Introduction

Intelligence has for a long time been acknowledged to be a significant predictor of academic success. Of course, intelligence is not a homogenous construct, different intelligence theories emphasize different aspects of cognitive functioning and problem solving. Especially the distinction between verbal and non-verbal intelligence is well established and is found in many intelligence tests (e.g. WISC-IV; Wechsler, Petermann, & Petermann, 2011). Both verbal and non-verbal intelligence are supposed to be relevant predictive factors for school achievement (besides other factors that are not discussed here).

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There is a long tradition of research on the determinants of school success, and intelligence has constantly proved to be of great importance, both for younger children (Schneider, Niklas, & Schmiedeler, 2014) and for older children in secondary school (Deary, Strand, Smith, & Fernandes, 2007).

Furthermore, children with lower intelligence often show severe learning problems leading to sub-average achievement (Henry & Winfield, 2010; Maehler & Schuchardt, 2009; Poloczek, Büttner, & Hasselhorn, 2012). In many countries children with lower intelligence attend schools for special education in order to receive special treatment that takes the lower learning potential into account.

Given this relation between intelligence and school achievement we expect children with normal intelligence to perform well at school and those with intelligence deficits to meet learning problems and to show failure to some extent, depending on the severity of the intellectual disability. But, contrary to these expectations, there are groups of children who do not perform according to these predictions: children with normal intelligence but sub-average school achievement and children with lower intelligence but average success at school.

The first group of children is characterized by special learning disabilities and is given the diagnosis "learning disorder" in ICD-10 (WHO, 2011). Depending on the area of failure "dyslexia" (ICD-10 F81.0) refers to difficulties in reading and writing, "dyscalculia" (ICD-10 F81.2) refers to difficulties in math and the diagnosis "mixed disorder of scholastic skills" (ICD-10 F81.3) is given for a category of disorders where both arithmetical and reading or spelling skills are significantly impaired, but the disorder cannot be explained in terms of general mental retardation or inadequate schooling. The essential criterion for all learning disorders is the discrepancy between (normal) intelligence and (sub-average) performance in standardized school achievement tests. Although there is an ongoing debate about the validity of the criterion of discrepancy (cf. Stanovich, 2005; Stuebing et al., 2002), which led the authors of DSM 5 to the decision to abandon this criterion, it is still the common practice in our country (Germany) when deciding about schooling and intervention.

The other group of children performing contrary to expectation could be called "overachievers". Here we describe children who perform well or at least at average at school although their measured intelligence is at a sub-average level. Of course we do not refer to children with moderate or severe intellectual disabilities, but to children at borderline of intelligence (IQ 70–85) or with mild intellectual disability (IQs between 60 and 70). These children should meet difficulties in reaching the major educational objectives of the given grade level, but in contrast they succeed in reading, writing and math. Probably there are not many of these students, and there are almost no studies with these children, as they are usually not identified. They attend regular schools and perform at their age level, so there is no need for special treatment or even diagnostic intervention.

Given these exceptions from the common relation of intelligence and academic success the question arises what other cognitive factors might explain school achievement. Currently working memory is being regarded as an important influencing factor and a lot of research is going on to determine the relative significance of both intelligence and working memory (cf. Cornoldi, Giofrè, Orsini, & Pezzuti, 2014). Working memory comprises several components whose coordinated activity is responsible for the manipulation and short-term storage of information.

The predictive role of intelligence and working memory in academic attainment has been investigated by Alloway and Alloway (2010). According to their findings working memory skills at 5 years of age were the best predictor of literacy and numeracy 6 years later, when children's school achievement was tested, while IQ proved to explain a smaller proportion of variance. Similar findings by Mähler, Piekny et al. (2015) point out the relevance of working memory skills besides domain-specific precursors for literacy and math in six year olds as predictors for school attainment at the end of first grade. Other studies with children at school age show that individual differences in working memory capacity predict and explain outcomes in reading, spelling and math (Alloway & Alloway, 2010; Hasselhorn et al., 2012), when all skills are tested at the same time.

Working memory deficits are also widely being discussed and identified as possible causal factors underlying learning disabilities (Cornoldi et al., 2014). Although various models of working memory have been developed, the British model by Baddeley (1986) has proved a particularly useful theoretical tool in numerous studies on learning disabilities. According to this model, working memory comprises three components: the modality-free *central executive*, which is a kind of supervisory system that serves to control and regulate the occuring cognitive processes, and two slave systems, the *phonological loop* and the *visual-spatial sketchpad*. The functions of the central executive identified by Baddeley (1996) include coordinating the slave systems, focusing and switching attention, and retrieving representations from long-term memory. The two slave systems perform modality-specific operations. Verbal and auditory information is temporarily stored and processed in the phonological loop. Two components of the phonological loop are distinguished: the phonological store and the subvocal rehearsal process. The visual-spatial sketchpad is concerned with remembering and processing visual and spatial information; it comprises a visual cache for static visual information and an inner scribe for dynamic spatial information (Logie, 1995; Pickering, Gathercole, Hall, & Lloyd, 2001).

Research has provided numerous indications that specific learning disabilities are associated with working memory impairments (Alloway & Gathercole, 2006; Cornoldi et al., 2014; Pickering, 2006). There is considerable evidence that children with specific reading disabilities have deficits in phonological processing and storage (Vellutino, Fletcher, Snowling, & Scanlon, 2004). Further evidence suggests that these children also experience deficits in central executive functioning (Brandenburg et al., 2014). For children with arithmetical disabilities empirical evidence reveals an impairment of the visual-spatial sketchpad (Passolunghi & Mammarella, 2010, 2012; Schuchardt, Maehler, & Hasselhorn, 2008) and of the central executive component (Passolunghi & Siegel, 2001), while findings on the phonological loop are inconsistent (see