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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

**Table 1**
Sex distribution and Means (Standard Deviations) of Age, IQ, Spelling *T*-Scores, Reading T-Scores, and Mathematics *T*-Scores by Subgroup.

| | LIQ-LA (N = 25) | LIQ-NA (N = 13) | NIQ-LA (N = 30) | NIQ-NA (N = 30) |
|---|---|---|---|---|
| Sex (m/f) | 17/09 | 9/4 | 13/17 | 15/15 |
| Age (years;months) | 8;10 (0.6) | 8;10 (0.35) | 8;9 (0.42) | 8;9 (0.31) |
| IQ | 76.52 (2.82) | 78.00 (2.45) | 98.83 (5.83) | 97.63 (4.52) |
| Spelling | 37.68 (6.38) | 48.46 (9.36) | 33.03 (4.90) | 49.47 (4.20) |
| Reading | 35.96 (5.55) | 48.62 (6.23) | 35.97 (4.90) | 51.30 (3.67) |
| Mathematics | 34.80 (8.27) | 49.08 (6.30) | 32.17 (3.54) | 51.40 (4.15) |

Swanson & Sachse-Lee, 2001 vs. Geary, Hamson, & Hoard, 2000; or Landerl, Bevan, & Butterworth, 2004). Examining the intellectual profiles of children with specific learning disabilities Cornoldi et al. (2014) also detected specific deficiencies in working memory (and processing speed, which is not discussed here).

The few existing studies with children with mixed disorders of scholastic skills conclude that these children exhibit both deficits, i.e., those found for specific disorders of arithmetic skills and for specific disorders of reading/writing, and to a greater extent (Landerl, Fussenegger, Moll, & Willburger, 2009; Pickering & Gathercole, 2004; Schuchardt et al., 2008).

Departing from this state of research, working memory skills can be considered as an important factor for academic achievement. Yet it is an open question if working memory can account for the unexpected academic success or failure of the two groups mentioned above—children with mixed disorders of scholastic skills and overachieving children with low intelligence. Therefore the aim of the present study is to analyse the working memory profiles of these children as compared to children performing in line with the typical expectations, that is typically developing children with average school achievement and children with intellectual disabilities and lower academic skills. In other words the research question was: Are there systematic differences in working memory depending on differences in intelligence and school achievement?

## 2. Method and materials

The research question was addressed in a factorial design with the two factors intelligence (normal vs. low) and school achievement (good vs. poor). Within this 2 (levels of intelligence) by 2 (levels of school achievement) factorial design working memory profiles of the resulting groups were analysed as the dependent variable.

### 2.1. Sample

Four groups of children participated in the study, each of them representing one group of the factorial design. Thirty children (normal intelligence, low school achievement: NIQ-LA) with the diagnosis "mixed disorder of scholastic skills" (ICD-10 F81.3; mean IQ 99, mean age 8;9 years), twenty-five children (low intelligence, low school achievement: LIQ-LA) with comparable learning disabilities but lower intelligence (mean IQ 77, mean age 8;10 years), thirteen children (low intelligence but normal school achievement: LIQ-NA), the so called "overachievers" (mean IQ 78, mean age 8;10) and a control group of typically developing children with normal IQ and regular school achievement: NIQ-NA (mean IQ 98, mean age 8;9). The sample is part of a greater longitudinal study on working memory of children with learning disabilities. The whole sample (2195 children) was recruited in three different parts of the country, and those who met our inclusion criteria took part in the longitudinal study. All children were recruited from regular public primary schools, no child attended a school for special education. All children were in grade 3 when this study took place. Their characteristics are summarized in Table 1.

### 2.2. Procedures and measures

Data were available for *intelligence* and *scholastic skills* (mathematics, reading and spelling) in order to match the four groups. These data were collected via classroom testing.

To obtain an estimate of general cognitive ability, children completed the German version of the *Culture Fair Intelligence Test 1* (CFT 1; Cattell, Weiß, & Osterland, 1997). Reading ability was assessed by *ELFE 1–6*, a German reading comprehension speed test (Lenhard & Schneider, 2006). The ELFE 1–6 consists of three subtests to be completed within a given time constraint. The first subtest assesses decoding and word recognition abilities while the second and third subtests measure reading comprehension on sentence and text level. A reading comprehension test was used rather than a reading accuracy test, as reading accuracy is usually high in transparent orthographies like German (Landerl, 2001), and consequently, does not differentiate sufficiently between good and poor readers. To assess spelling ability, the *WRT 2+*, a German spelling test for second and third graders (Birkel, 2007), was administered to children. This test requires children to spell 43 dictated words embedded in short sentences. To assess school achievement in math children completed the DEMAT 2+, a German curricular valid test for children in second and third grade (Krajewski, Liehm, & Schneider, 2004). The DEMAT 2+ assesses mathematical competencies in the three domains of basic arithmetics, magnitude comparison and geometry.

To assess *working memory* as the dependent variable a rather long battery of working memory tasks, designed in accordance with the working memory model of Baddeley (1986), was presented to the children in individual sessions. Fourteen subtests from the computerized *Working Memory Test Battery for Children aged Five to Twelve Years* (AGTB 5–12; Hasselhorn et al., 2012) were administered. Nine of these subtests are span measures with an adaptive testing procedure: They start with a two-item sequence (for backward spans) or a three-item sequence (for forward spans), and sequence length is adjusted after each response. Sequence lengths may increase to a maximum of seven items (for backward spans) or eight items (for forward spans). The longest correctly repeated sequence is taken as the span score. Below the different tasks are described in more detail.

#### 2.2.1. Phonological loop

In digit span, increasing sequences of different digits are presented auditory at the rate of one digit every 1.5 s. The children's task is to repeat the sequence orally in the same serial order as presented. Digit span is a measure for the overall functional capacity of the phonological loop, because both phonological storage and rehearsal are involved when performing this task (e.g., Hasselhorn, Grube, & Mähler, 2000). Similarly, the word span tasks require the serial repetition of increasing sequences of words, which are presented auditory at the rate of one word every 1.5 s. Monosyllabic and trisyllabic familiar German words are presented to the children resulting in separate span scores for short and long words, respectively. In nonword repetition, children repeat nonwords (e.g., limparett, jalosse) immediately after their auditory presentation. The task consists of 24 nonwords differing in the number of syllables (i.e., three, four, and five syllables. The number of syllables was mixed for presentation. An oral repetition that included all phonetic elements of the nonword was scored as accurate and the total number of correct repetitions served as the test score. Nonword repetition is used as an indicator for the phonological store. To assess the speed of subvocal rehearsal, an articulation rate task was administered to children: Children repeated a given triplet of monosyllabic nouns as quickly as possible, ten times in a row. The time needed to articulate each triplet was recorded and the four shortest triplets were transformed into a measure of mean articulation rate (in syllables per seconds). There were two trials of the task using different word triplets and articulation rate was averaged across both trials.

#### 2.2.2. Visuospatial sketchpad

The static component of the sketchpad (i.e., the visual cache), was assessed with a matrix span task: A pattern composed of two to eight black squares was presented on the screen within a 4 by 4-matrix. The pattern was then replaced by an empty matrix, on which the children had to tap the squares that had been blackened beforehand. The presentation time of the pattern increased linear to its complexity by 1200 ms per blackened square. In corsi span, nine white squares are distributed randomly on a grey screen. A smiley appears in one of these squares for 950 ms and then lights up in another square after an interstimulus interval of 50 ms. At the end of each trial, the children had to touch the squares the smiley had emerged in correct serial order. Due to its sequential presentation format, the corsi span task captures the inner scribe of the sketchpad (e.g., Logie, 1995).

#### 2.2.3. Central executive

The central executive was assessed with both backward spans and more complex span tasks involving both the simultaneous processing and short-term storage of information. These tasks tap the central executive in combination with the phonological loop, and are, therefore, considered to reflect verbal working memory (Savage, Lavers, & Pillay, 2007, for a review). The *digit span backwards* and the *word span backwards* are identical to the forward condition of the tasks except that the children were instructed to recall the sequences in reverse order. In a similar way *colour span backwards* requires the repetition of the colour of circles presented on the screen in reverse order. Backward recall is considered to tap central-executive functioning, because reversing the stimulus order during recall increases processing load in children's working memory (see Gathercole, 1998). In *counting span*, blue squares and dots of varying number are distributed randomly on a white screen. Having counted aloud all the dots, the children pressed a button to start the presentation of the next image. At the end of a trial, children are asked to recall the dots total in correct serial order. In *object span*, an increasing number of objects (e.g., candle, cheese) are presented one by one on the screen and children are instructed to classify whether the presented object is eatable or not. Subsequently, children are asked to recall orally all the objects in correct serial order. The *go-/nogo-task* is considered to tap inhibition as a central executive function. Children have to make quick decisions about certain features being visible or not. In the beginning children are familiarized with target attributes (eg. blue trousers and yellow balloon). Subsequently 24 items with pictures of children either representing the features or not are presented. The task for the children is to decide as quickly as possible if the presented picture is a target or a distractor item; when the target attributes are to be seen in the picture the child is supposed to press a button, otherwise to inhibit the reaction. The number of correct reactions (go and nogo) forms the test score. For a similar purpose the *stroop task* assesses the children's competence to focus on relevant and to inhibit irrelevant information. On the screen the child sees a drawing of a man or a woman and simultaneously hears the word "man" or "woman". In the congruent condition (12 items) visual picture and acoustic information are compatible, in the incongruent condition (12 items) they do not match. The task for the child is to focus on and react according to the visual stimuli (press a button) and to ignore the acoustic information. The test score here is the median of the reaction time of correct responses in the incongruent condition.

**Table 2**
Means (Standard Deviations) for Working Memory Measures by Subgroup.

| | LIQ-LA | LIQ-NA | NIQ-LA | NIQ-NA |
|---|---|---|---|---|
| Phonological loop | | | | |
| Digit span | 4.44 (0.58) | 4.92 (0.76) | 4.33 (0.66) | 5.00 (0.74) |
| One-syllable word span | 3.84 (0.62) | 4.23 (0.73) | 3.87 (0.82) | 4.40 (0.68) |
| Three-syllable word span | 3.28 (0.46) | 3.54 (0.66) | 3.24 (0.51) | 3.50 (0.51) |
| Articulation rate | 3.16 (0.71) | 3.39 (0.68) | 2.98 (0.57) | 3.25 (0.54) |
| Nonword repetition | 14.12 (4.06) | 15.62 (3.73) | 14.33 (4.55) | 16.23 (4.58) |
| Visual-spatial sketchpad | | | | |
| Corsi-block span | 4.36 (0.76) | 4.54 (0.66) | 4.70 (0.75) | 4.70 (0.57) |
| *Matrix span* | 4.52 (1.12) | 5.54 (1.05) | 5.13 (1.22) | 5.33 (1.15) |
| Central executive | | | | |
| Backward digit span | 3.20 (0.58) | 3.85 (0.90) | 3.37 (0.56) | 3.83 (0.83) |
| Backward word span | 3.04 (0.54) | 3.54 (0.66) | 3.29 (0.54) | 3.60 (0.56) |
| Backward colour span | 3.00 (0.82) | 3.54 (0.97) | 3.33 (0.88) | 3.47 (0.86) |
| Object span | 3.20 (0.82) | 3.54 (0.97) | 3.38 (0.68) | 3.53 (0.86) |
| Counting span | 3.28 (0.68) | 3.62 (1.04) | 3.27 (0.74) | 3.90 (0.85) |
| Go/NOGO | 19.36 (2.18) | 20.23 (1.64) | 20.50 (1.85) | 20.17 (2.33) |
| Stroop | 1219.92 (392.66) | 1305.19 (501.52) | 1129.02 (362.08) | 1068.43 (339.04) |

## 3. Results

All collected data of the different memory tasks were analyzed in a 2 (intelligence normal vs. low) by 2 (scholastic skills good vs. poor) factorial design. The results of the different subsystems were calculated separately.

Table 2 presents means and standard deviations for all working memory measures of the four subgroups.

### 3.1. Phonological loop

The scores of the five tasks assessing phonological loop functioning were entered into a MANOVA. The multivariate main effect for scholastic skills, $F(5, 165) = 6.20$, $p < 0.001$, $\eta_p^2 = 0.16$, proved to be significant. The multivariate main effect for intelligence, $F(5, 165) = 1.81$, $p = 0.11$, $\eta_p^2 = 0.05$, and the intelligence by scholastic skills interaction were not significant, $F(5, 165) < 1$. For the school achievement factor, univariate tests showed significant differences between groups on all phonological tasks (digit span: $F(1, 169) = 27.77$, $p < 0.001$, $\eta_p^2 = 0.14$; one-syllable word span: $F(1, 169) = 15.20$, $p < 0.001$, $\eta_p^2 = 0.08$; three-syllable word span: $F(1, 169) = 9.25$, $p = 0.003$, $\eta_p^2 = 0.05$; articulation rate: $F(1, 169) = 3.95$, $p = 0.049$, $\eta_p^2 = 0.03$; nonword repetition: $F(1, 169) = 9.57$, $p = 0.002$, $\eta_p^2 = 0.05$).

### 3.2. Visual spatial sketchpad

The scores on the two tasks assessing visual-spatial sketchpad were entered into a multivariate analysis of variance (MANOVA). The multivariate main effect for school achievement, $F(2, 169) = 5.10$, $p = 0.007$, $\eta_p^2 = 0.06$, proved significant. In contrast, the multivariate main effect for intelligence, $F(2, 169) = 2.84$, $p = 0.06$, $\eta_p^2 = 0.03$, and the school achievement by intelligence interaction, $F(2, 169) < 1$, were not significant. For the school achievement factor, univariate tests of visual-spatial working memory tasks showed significant differences between groups on matrix span, $F(1, 170) = 10.26$, $p = 0.002$, $\eta_p^2 = 0.06$, but not on the corsi-block, $F(1, 170) = 1.55$, $p = 0.22$, $\eta_p^2 = 0.01$.

### 3.3. Central executive

Finally, the scores on the seven tasks assessing central executive were entered into a multivariate analysis of variance (MANOVA). The multivariate main effect for school achievement, $F(7, 160) = 4.38$, $p < 0.001$, $\eta_p^2 = 0.16$, was significant. In contrast, the multivariate main effect for intelligence, $F(7, 160) = 1.95$, $p = 0.065$, $\eta_p^2 = 0.16$, and the interaction of the two factors were not significant, $F(7, 160) < 1$. For the school achievement factor, univariate tests showed significant differences between groups on all central executive memory tasks (digit span backwards: $F(1, 166) = 18.47$, $p < 0.001$, $\eta_p^2 = 0.10$; word span backwards: $F(1, 166) = 13.13$, $p < 0.001$, $\eta_p^2 = 0.07$; colour span backwards: $F(1, 166) = 7.09$, $p = 0.009$, $\eta_p^2 = 0.04$; Object span: $F(1, 166) = 7.34$, $p = 0.007$, $\eta_p^2 = 0.04$; counting span: $F(1, 166) = 12.50$, $p = 0.001$, $\eta_p^2 = 0.07$, with the exception of the GO/NOGO task, $F(1, 166) < 1$, and the Stroop task, $F(7, 166) < 1$.

## 4. Discussion

The aim of the present study was analyze the working memory functions of children with either expected (NIQ-NA and LIQ-LA) or unexpected (HIQ-LA and LIQ-HA) levels of school achievement depending on their intelligence. Results reveal a significant main effect for the factor school achievement for all subsystems (phonological loop, visual spatial sketchpad, central executive) while the main effect for intelligence proved insignificant. There were no significant interactions of school achievement and intelligence.

Very clearly our results corroborate the notion that working memory functioning plays an important role for school attainment. Given the significant main effects for school achievement and insignificant main effects for intelligence and the absence of any interaction effects, we conclude that working memory differences may account for school achievement irrespective of intelligence level. We found that children with sub-average school achievement showed deficits in working memory functioning, and this was true both for children with mixed disorders of scholastic skills who do not have any intellectual deficit and for children with lower intelligence. By contrast, children with regular school achievement did not show deficits of working memory, again irrespective of their level of intelligence. This was expected for typically developing children but was a very interesting finding with respect to the "overachievers", i.e. the group with lesser intelligence. These children seemed to be able to compensate for their lower intelligence through unimpaired working memory functioning. Of course we must take into account that this group of children was small and we must admit that children with this cognitive profile are rare (we only found 13 children in a total sample of 2195 children), which is a clear limitation of the study and should lead us to refrain from emphasizing this result too strongly. But nevertheless working memory functioning may give an explanation for the average academic success of these children. Given the limited information about other characteristics of our sample we hesitate to add any speculations about possible causes that might have been responsible for the compensation of low intelligence. Future research might concentrate on environmental factors such as supporting families or teachers.

Given our pattern of results we come back to the discussion, what factors significantly contribute to academic achievement. In line with other researches we conclude, that working memory seems to be the more important predictor for academic achievement: Children with normal intelligence seem to fail at school when their working memory is impaired (the group with mixed disorders of scholastic skills) and children with low intelligence may succeed well at school as long as their working memory is unimpaired (the "overachievers"). This conclusion is supported by other findings, which suggest, "that the specificity of associations between working memory and attainment persist after statistically controlling for differences in IQ" (Alloway & Alloway, 2010; Alloway, 2007). Furthermore longitudinal studies that predict later school attainment from earlier intelligence and working memory functioning strengthen the higher significance of working memory (Alloway & Alloway, 2010; Preßler, Könen, Krajewski, & Hasselhorn, 2014).

Other positions might argue that there is a significant overlap of the two constructs and it is due to differences in conceptualization and measurement how big the overlap is. In line with this argument Cornoldi and Giofrè (2014) refer to the high correlation between intelligence and working memory, especially when intelligence is measured via intelligence tests that include subtests requiring short-term memory or working memory performance like the Wechsler Intelligence Scales. For our study and the separation of the groups we tried to be very conservative. We used a test of non-verbal IQ to measure intelligence, which is rarely or not at all overlapping with the used working memory measures. This may be different in tests that include also verbal IQ measures; there we would not expect such a clear dissociation as we found it.

If school success is not necessarily linked to intelligence (alone), as is true for our unexpectedly succeeding overachievers and unexpectedly failing children with mixed disorders of scholastic skills, measures of working memory should be taken into account for diagnosis and prognosis of development of attainment. We should pay attention to children with deficient working memory functions because these children are obviously at risk for school failure.

And, once again, these results contribute to the ongoing debate about the validity of the criterion of discrepancy for diagnosis of learning disorders as used within ICD-10. In our study, children with learning difficulties differed in terms of intelligence but they were characterized by the same underlying working memory deficits. Thus, we could conclude that the two groups with poor school achievement (LIQ-LA and NIQ-LA) are more similar than their different IQs might suggest and therefore should not be treated as suffering from fundamentally different learning problems (which is the rationale of the criterion of discrepancy). The criterion of discrepancy is about to be abandoned in many countries and is no longer in use in DSM 5—and our results may be taken as an argument in favor of this development.

The present and future challenge will still be the adequate treatment for children with regard to their differential intellectual and working memory potential. One obvious suggestion could be that working memory training might be an eligible intervention for students showing early academic failure. Yet, empirical evidence cannot clearly recommend this treatment: In an extensive meta-analysis Melby-Lervåg and Hulme (2012) concluded, that some short-term enhancements of working memory can be achieved via working memory training, but long-term improvements are rare and substantial transfer to school achievement did not occur. The same pattern of results was found in our own working memory training for children with dyslexia, an extensive computerized adaptive training program based on the Baddeley model of working memory (Mähler, Jörns, Radtke, & Schuchardt (2015)). Therefore, to date, the problem how to cope with or to compensate for deficient short-term memory and working memory functions remains to be solved.

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