Working memory in children with mild intellectual disabilities:

Abilities and training potential

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Het werkgeheugen van kinderen met
een lichte verstandelijke beperking:
Vaardigheden en trainingsmogelijkheden
(met een samenvatting in het Nederlands)

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1

Introduction and theoretical background

Introduction

This thesis concerns the short-term memory and working memory abilities of children with mild intellectual disabilities (MID). Working memory is of great importance for learning and daily functioning, but it is hardly studied in children with MID. Short-term memory and working memory strengths and weaknesses in these children are explored by comparing their performance with that of control groups of typically developing children. In addition, everyday memory is studied as it is assumed to rely on short-term memory and working memory processes. Finally, a computerized working memory training is developed and it's effectiveness on working memory performance and related cognitive abilities is investigated.

In the present chapter, the theoretical background is presented for providing a context of our studies of working memory in children with MID. The focus is on, respectively, definition of mild intellectual disabilities, the cognitive abilities of children with MID, definition of working memory, current knowledge on working memory in children with MID, the relevance of studying everyday memory in these children, and training of their working memory potential. Thereafter, the specific research questions will be presented. Finally, the content of the thesis will be briefly outlined.

Theoretical background

Mild intellectual disabilities

Research on children with mild intellectual disabilities (MID) is somehow a rare phenomenon. When searching in the literature base Pubmed on 'mild intellectual disabilities' it gives only 60 hits (April, 7th, 2008). In contrast, a search on Down syndrome gives 18.378 hits, on Autism 8.538 hits and Attention Deficit Hyperactivity Disorder (ADHD) 7.082 hits. This is rather intriguing as the prevalence of MID exceeds by far the prevalence of any of the other mentioned disorders (e.g., Heikura et al., 2005; Simonoff et al., 2006; Weijerman et al., 2008). A plausible reason for this discrepancy is the clarity of what is meant by the classifications Down syndrome, Autism and ADHD, while the dimensional based term 'mild intellectual disabilities' lacks this clarity.

Intellectual disability is defined by most classification systems as having significant limitations both in intellectual functioning and in adaptive behavior skills (DSM-IV-TR, American Psychiatric Association, APA, 2000; ICD-10, World Health Organisation, WHO, 1993; American Association on Intellectual and Developmental Disabilities, AAID, see Luckasson et al., 2002). The lower intellectual functioning of people with MID is considered to be reflected by an IQ score in the range 55 – 70 (DSM-IV-TR, APA, 2000; ICD-10, WHO, 1993) or 55 – 75 (AAIDD, Luckasson et al., 2002). This difference in range underscores the relativity of the IQ score. It is well known that different intelligence tests yield different IQ scores (e.g. Edwards & Paulin, 2007; Miller & Gilbert, in press). In fact, IQ scores change with age, generally they rise (Kanaya, Ceci, & Scullin, 2003), and they rise in populations in developed countries over time, the so-called Flynn effect (e.g. Flynn, 1987), which means that newly introduced norms of the same task result in lower IQ scores (Kanaya et al., 2003). While the limitations in intellectual functioning are difficult to reliably detect, adaptive behavior skills, the second aspect of intellectual disabilities, is even more difficult to measure and classify. Examples of such abilities are conceptual skills like reading and writing, social skills like taking responsibility and avoiding victimization and practical skills like eating, mobility and managing money (AAID, 2002). Only recently an attempt has been made to develop a guideline on how to measure and judge adaptive behavior skills in The Netherlands (Ponsioen & Verstegen, 2006). This is not to say that adaptive behavior skills are not important to consider. On the contrary, in Dutch policy children with an IQ score between 70 and 85 are considered mildly intellectually disabled when aspects of their adaptive behavior skills are deviant (Landelijk Kenniscentrum LVG, 2008). It is considered that these children can profit as well from the special care and education given to children with an IQ score between 55 and 70 (Landelijk Kenniscentrum LVG, 2008) and therefore settings for special care and special education for children with MID use the 55 – 85 range (Konijn, De Graaf, & Van den Berg, 2004; in residential care for adults even an IQ range of 50 – 90 is used; Tenneij & Koot, 2006). In addition, when children have an IQ score between 55 and 70, but they do not show deviant adaptive behavior, they are officially not considered to be mildly intellectually disabled. In fact, many of the children with an IQ score within that range will not be assessed on an intelligence test as their behavior simply does not give reason to do so, hence, they will never be considered mildly intellectually disabled (Macmillan, Siperstein, & Gresham, 1996; Ponsioen & Van der Molen, 2002; Simonoff et al., 2006). Indeed, a British study investigating IQ scores of pupils in schools in a specific borough, revealed that the largest part of children with an IQ score between 55 and 70 followed regular education, only 15% of the children with an IQ score in that range had a statement of special educational needs or attended a school for moderate learning difficulties. It was their behavior that predicted educational identification (Simonoff et al., 2006).

Considering the above, it comes as no surprise that children with MID do have more emotional and behavioral problems than typically developing children (Dekker, Koot, Van der Ende, & Verhulst, 2002) and boys with MID are at a higher risk to develop delinquent behaviour at a later age than typically developing boys (Douma, Dekker, Verhulst, & Koot, 2006).

MID in this thesis

In this thesis, the focus is on children with mild intellectual disabilities defined according to the descriptions above: they have an IQ score between 55 and 85, have additional problems with adaptive behavior skills and (thus) attain schools for special education.[1] Pervasive Developmental Disorders (PDD) and ADHD were both contra-indications as both disorders are associated with their own specific working memory profile, which would interfere with the profile of MID (Gathercole & Alloway, 2006).

[1] Except for the children described in chapter 4 where the IQ score range 55 – 70 is applied following a review of this paper in a journal in which conventions about the definition of MID are based on current prevailing practices in the United States of America.

Developmental – difference debate

The cause of MID in children is generally considered to be a combination of deviations in several genes and a disadvantageous social environment or prenatal circumstances (Ramakers & Ponsioen, 2007). However, a Finish study showed that in most cases, the cause of the disability remains unknown (Heikura et al., 2005).

One generally accepted view is that the cognitive abilities of people with non-organically based intellectual disabilities fall at the lower end of the normal distribution, and hence develop like people with average intellectual functioning but at a slower rate. In addition, their development is supposed to come to a hold at a lower level than in the typically developing population (Bennet-Gates & Zigler, 1998). This so-called developmental theory contrasts the difference theory: the development of people with intellectual disabilities, both organically and non-organically based, show specific deficits in cognitive functioning and proceeds atypical in comparison to the development in the typically developing population (Bennet-Gates & Zigler, 1998). For children with MID, having an IQ score between 55 and 85 but also additional adaptive problems, it is not clear which of both views holds most. As indicated above, the cause of MID is mostly unknown and can have an organically and / or familial origin. In line with this, the abilities of children with MID will then show, respectively, defects and / or delays. When one speaks of a developmental delay, the abilities of, in this case children with MID, are expected to be at a lower level than the abilities of chronological age matched typically developing children (CA control group). However, some people argue that comparing the performance of children with intellectual disabilities with CA control children is not informative. For example, Bayliss, Jarrold, Baddeley, and Leigh (2005, p. 81) stated:

> *"Because individuals with generalized learning difficulties are, by definition, expected to perform at a lower level than their chronological age-matched peers in most areas of functioning, equating the groups on their developmental level or mental age is more informative in terms of identifying specific areas of strength or difficulty".*

In case children with MID also perform less well than mental age matched typically developing children (MA control group), one speaks of a defect: their abilities are below the level of what could be expected based on their mental age. Bennet-Gates and Zigler (1998) argue that only by comparing the abilities of children with (mild) intellectual disabilities with the abilities of both control groups it can be revealed if these are delayed or defect.

Cognitive abilities of children with MID

To date, not much is known about cognitive abilities of children with MID (e.g., Ponsioen, 2001). Yet, knowing more about those abilities (strengths and weaknesses) can lead to more effective didactic strategies, both in communication and in intervention (Ponsioen, 2001; Ruijssenaars, 2001) and may result in a better well-being (Ramakers & Ponsioen, 2007). In his study, Ponsioen (2001) concluded that children with MID hardly differ from CA control children on response inhibition and mental flexibility. However, the children with MID were less able to monitor their own actions and therefore were less accurate. A plausible reason for this finding is the fact that the children with MID perform quite well when tasks are well structured, but they perform worse when tasks lack this structure. This might also be the reason why children with MID often fail on such tasks in everyday life, as they are not able to adequately analyze and integrate relevant stimuli (Ponsioen, 2001). This is illustrated by a study on social information processing (Van Nieuwenhuijzen, 2004) which showed that children with MID, compared to CA control children, focus more on verbal and on negative cues. Furthermore, they tend to generate more responses, possibly because of a lack of inhibition (Van Nieuwenhuijzen, 2004). Indeed, social cognition seems weak in children with MID: they have difficulty understanding the action of others and anticipating on behavior of others (Collot d'Escury, 2007). This might possibly be explained by a weak WM, since unstructured tasks place more demands on WM ability. As stated by Moses, Carlson, and Sabbagh (2005, p. 135)

> *"Effective social cognition requires both the ability to hold in mind competing perspectives as well as the ability to suppress those perspectives that are irrelevant when a specific mental state attribution is required".*

In sum, children with MID perform quite well when the tasks are simple and structured, however, when tasks become more complex, which is mostly the case in everyday life, children with MID perform poorly (Collot d'Escury, 2007). It seems that the difficulties children with MID experience in everyday life are partly caused by the inability to store and manipulate information simultaneously in face of a demanding task (Ponsioen & Van der Molen, 2002), requiring the constructions of relatively complex structural representations (Oberauer, 2005). In other words, the observed everyday life weaknesses of children might be partly caused by a weak WM.

Working memory

Working memory (WM) is, as Miyake and Shah (1999, p. xiii) postulate, *"one of the 'hottest' topics in cognitive psychology and cognitive neuroscience"*. It refers to the ability to temporarily store and manipulate information simultaneously (Baddeley, 1986; Cowan, 1999; Engle, Kane, & Tuholski, 1999) and plays an important role in scholastic activities, including language comprehension (e.g., Friedman & Miyake, 2004), reading (e.g., Hitch, Towse, & Hutton, 2001) and arithmetic / mathematics (e.g., Bull & Scerif, 2001). In this thesis the working memory model of Baddeley (1986, adapted and extended in 2000, originally Baddeley & Hitch, 1974), probably the most influential model (Engle, Tuholski, Laughlin, & Conway, 1999; Garon, Bryson, & Smith, 2008) was used. In this model, WM is conceptualized by four components (see Figure 1). The visuo-spatial sketchpad and the phonological loop are responsible for the temporary storage of respectively visuo-spatial and verbal information (visuo-spatial short-term memory and verbal short-term memory). The phonological loop also has an automatic rehearsal function, present in typically developing children from 7 years old on (Gathercole & Hitch, 1993), which prevents information to fade away. Both so-called 'slave systems' are co-ordinated by the central executive, an attentional control system. Tasks relying on both one of the short-term memory (STM) stores and the central executive are said to be WM tasks. Furthermore, in 2000, Baddeley added the fourth component, the episodic buffer, which stores information in a multi-dimensional code and serves as a temporary interface

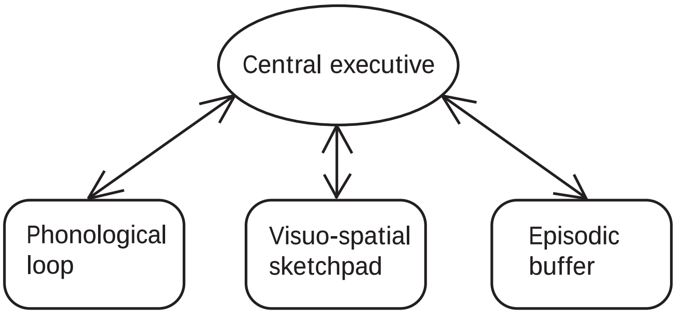


Figure 1 Baddeley's working memory model (2000).

between the two slave systems and long-term memory and is controlled by the central executive as well. As the episodic buffer is theoretically still very much in development and as yet hardly measured (but see Alloway, Gathercole, Willis, & Adams, 2004), it was not considered in this thesis. To assess visuo-spatial STM, verbal STM, verbal WM and visual WM in this study, tasks were used as illustrated in Table 1.

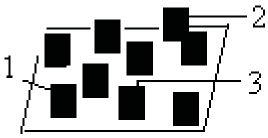
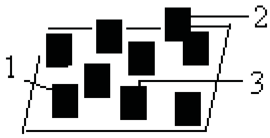
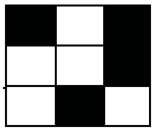
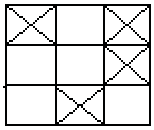
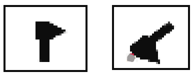
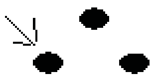
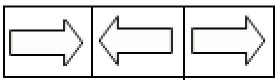
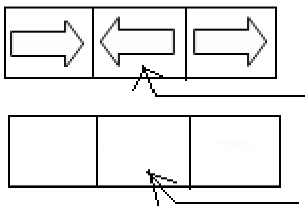
Research has shown justification for Baddeley's WM model for use in both typically developing adults (see Oberauer, 2005, for an overview) and children from 4 years old on (Alloway, Gathercole, & Pickering, 2006), showing a linear improvement on STM and WM measures from 4 to 14 years, levelling off between 14 and 15 years[2] (Gathercole, Pickering, Ambridge, & Wearing, 2004). Furthermore, research shows that besides a conceptual framework, performance on STM and WM tasks relies on different brain regions (e.g. Baddeley, 2003). This is illustrated by the activation of the ventrolateral prefrontal cortex when STM tasks are carried out versus the activation of the mid-dorsolateral prefrontal cortex when WM tasks are being performed (e.g. Crone, Wendelken, Donohue, Van Leijenhorst, & Bunge, 2006).

Baddeley's WM model is not only useful within the typically developing population, but also in clinical populations. For instance, studies in populations with neurodevelopmental disorders show that specific disorders are associated with specific WM profiles. People with Down syndrome for example, show relatively more problems with the phonological loop, while people with Williams syndrome show a specific visuo-spatial sketchpad weakness (see for an overview Gathercole & Alloway, 2006).

Moreover, Baddeley's WM model is very detailed in terms of the different components and tasks measuring those components (Baddeley, 1986; Working Memory Test Battery for Children, WMTB-C, Pickering & Gathercole, 2001; Automated Working Memory Assessment, AWMA, Alloway, 2007). Performance on these tasks is subject to a large degree of individual variation (Alloway, 2006) and it is suggested that batteries of those tasks, like the AWMA, can be used for clinical practice (Gathercole, Lamont, & Alloway, 2006). All this taken together, Baddeley's WM model offers excellent prerequisites for use in children with MID.

[2] The performance on the Visual Patterns Test, a test measuring visual STM, levels of at 11 years.

Table 1 Short-term memory and working memory tasks used in the thesis

Task (ref)	Measures	Example	Demand	Required response
Digit Recall (Baddeley, 1986)	Verbal STM	6, 3, 5…	Repeat in the same order	'6, 3, 5'
Nonword Recall (Baddeley, 1986)	Verbal STM	Jar, lut, pog…	Repeat in the same order	'Jar, lut, pog'
Corsi or Block Recall (Pickering & Gathercole, 2001)	Visuo-spatial STM		Tap the same blocks in the same order	
Visual Pattern test (Della Sala, Gray, Baddeley, & Wilson, 1997)	Visuo-spatial STM		Mark the squares which were black	
Listening Recall (Pickering & Gathercole, 2001)	Verbal WM	Oranges live in water… Roses smell nice…	Decide if each sentence is true or false and at the end, repeat the last word of each sentence in the same order	'No' 'Yes, … water, nice'
Backward Digit recall (Pickering & Gathercole, 2001)	Verbal WM	8, 3, 5…	Repeat in backward order	'5, 3, 8'
Spatial span (Alloway, 2007)	Visual WM		Decide if the figure with the grey dot is the same or opposite to the left figure. Then, point to where the grey dot was placed.	'opposite…  '
Odd-One-Out (Henry, 2001)	Visual WM		Decide which symbol is different from the other two (the odd-one-out). Then, point to the place where the odd-one-out was placed.	

Working memory in children with MID

To the best of our knowledge, until the start of the research for this thesis in 2004, only one study examined visual and verbal STM and WM functioning in children with an IQ score between 55 and 85. Henry (2001) compared a group of children with an IQ score between 70 and 85 and a group of children with an IQ score between 55 and 70 to a CA control group on a variety of tests measuring STM (Word Recall, Digit Recall, Spatial span, Pattern span) and WM (Listening Recall, Backward Digit Recall, Odd-One-Out test, see Table 1). The group in the lower IQ score range showed delays on all the administered STM and WM tasks compared to the CA group. The group in the higher IQ score range showed delays on verbal STM tasks compared to the control group, but their visuo-spatial STM and verbal WM appeared to be intact. Although it is a well conducted study, it does not detail the specific strengths, especially of the children with the lower IQ scores. Therefore, in our study we used both a CA control group and a MA control group. In addition, it is not known if children with MID show automatic rehearsal, an important prerequisite to prevent information for fading away, although it is expected that they do so when their mental age is above 7 years (Gathercole & Hitch, 1993). Furthermore, it is not known if subgroups exist in terms of WM strengths and weaknesses within the group of children with MID. The present thesis tries to offer clarity on the above issues.

Knowing more about WM strengths and weaknesses in children with MID offers professionals and parents insight in the abilities of these children as well as information on how to communicate with them in the most suitable way. Furthermore, it can and should lead to didactic adaptations to the children's abilities so as to optimize learning conditions. For example, the contribution of verbal STM to cognitive development is considered mainly as supporting vocabulary acquisition (Baddeley, Gathercole, & Papagno, 1998). Therefore, a weak verbal STM at an early age might predict a rather weak vocabulary development and, at later age, difficulties with learning new languages. If besides a weak verbal STM, WM is intact, learning in general will not be a problem. However, special attention might be given to repeating lists of items to remember (like foreign words) till they are automated and held in mind. In contrast, a weak WM can lead not only to several scholastic delays, but also poses problems in everyday situations. This is nicely illustrated by an observational study that investigated the behavior of typically developing children with a diagnosed WM problem in the classroom. These children repeatedly forgot instructions, lost track in complex tasks, for example while writing down sentences produced by the teacher, and tend to withdraw in group conversations (Gathercole et al., 2006). These WM problems should make the teacher, among other things, speak in short sentences, repeat those sentences, offer structure in the demands and teach the pupils to indicate if they forgot what they have to do (Gathercole et al., 2006), all to reduce the WM demands.

Everyday memory

As indicated above, scholastic activities depend on STM and WM processes. In addition, many activities in everyday life outside the classroom depend on STM as well, like when remembering a telephone number or the graphemes of an unknown word long enough to be able to write it down (Gathercole, 1999). In addition to STM demands, everyday life requires WM processes as well (Baddeley, 1986; Engle et al., 1999). This happens, for example, when one has to step out of a routine activity like driving to the dentist instead of the usual trip to work (Unsworth & Engle, 2007). These so-called everyday memory (EM) activities are necessary for leading an independent life (Kazui et al., 2005) and therefore, understanding how it works in children with MID is crucial to improve support at an individual level. However, it is not known how children with MID perform on memory tasks in everyday life and how it correlates with their WM functioning. Therefore, these questions will be tackled in the present thesis.

Working memory training in children with MID

Besides the fact that the study outcomes can lead to immediate practical implications, they also offer a lead for further research. If WM is a weak cognitive ability in children with MID and knowing that WM is crucial for the development of, among other things, scholastic abilities and EM activities, then what are the possibilities to train this ability effectively? It has been suggested that even a small increase in the efficacy of WM will lead to significant improvements in classroom and daily life functioning in children (Minear & Shah, 2006). However, most trainings for children with (mild) intellectual disabilities focus on improving strategy use (Van Lieshout, 2001), like rehearsing incoming verbal information (e.g. Conners, Rosenquist, Arnett, Moore, & Hume, 2008), while WM training has never before been tried in populations with intellectual disabilities (Minear & Shah, 2006). Studies in other populations have illustrated that WM can be successfully trained, for example in children with ADHD (Klingberg et al., 2005) and children with acquired brain injuries (Van 't Hooft et al., 2007). In the last study (see Chapter 5), a computerized training is offered to children with MID in an attempt to train WM and to explore its generalizing effects on other cognitive abilities. If such a basic cognitive training can be effective for children with MID, it would offer a wealth of possibilities to explore, extend and implement such trainings alongside the regular curriculum for these children.

Research questions

The focus of the present thesis is on STM and WM abilities in children with MID. The two main objectives of this thesis are a) to unravel WM strengths and weaknesses in children with MID, and b) to investigate if WM can be trained effectively in these children. If children with MID perform less well than CA control children but as good as MA control children, it suggests that the memory abilities develop typically, but delayed. However, when the children with MID perform less well than the MA control children too, it indicates that their abilities are not merely delayed, but even defect. In addition to STM and WM, also EM is investigated in children with MID by comparing their EM performances with both control groups. Furthermore, it is investigated if EM activities rely on STM and WM processes for the three groups of children. A computerized WM training will be offered to children with MID to investigate if WM can be effectively trained and if it sorts effect on other, related cognitive abilities.

The following research questions will be addressed:

1. Do children with MID show a developmental delay or a deficit in STM and WM abilities? (Chapters 2 and 3)
2. Do children with MID show automatic rehearsal within the phonological loop? (Chapter 2)
3. Do subgroups exist within the broader category of children with MID, each with their own specific STM and WM profiles? (Chapter 3)
4. How do children with MID perform on EM tasks? (Chapter 4)
5. Is EM related to WM in children with MID? (Chapter 4)
6. Can WM be effectively trained in children with MID and if so, does it affect other cognitive abilities? (Chapter 5)

Outline of the thesis

Chapter 2 presents research investigating the phonological loop and its automatic rehearsal aspect in children with MID. Furthermore, it focuses on several functions of the central executive. Both aspects, the phonological loop and the central executive, are part of Baddeley's WM model and hence can be called WM aspects. However, the ability to store and process information simultaneously is not assessed in this part of the study.

Chapter 3 gives insight into the WM strengths and weaknesses in children with MID by comparing their results on verbal and visuo-spatial STM and on verbal and visual WM tasks with CA and MA control children. Although we tried to homogenize the population by excluding children with ADHD and children with PDD, as both populations appear to have their own specific WM profiles (e.g. Gathercole & Alloway, 2006), it still remains a rather heterogeneous population. With hierarchical cluster analyses, we tried to identify subpopulations in clinical phenotypes based on cognitive functioning.

The goal of Chapter 4 is to find out how children with MID perform on ecologically valid memory tasks, that is, on memory tasks that children face in everyday life. The performances on these EM tasks were correlated with WM tasks. We expected a connection between the two as EM tasks might be relatively demanding for children with MID, hence making them rely on their WM processes, whereas the CA control children might more rely on automated processes.

In Chapter 5, our study on training WM in children with MID is described. Earlier studies showed that training WM might be effective in for example children with ADHD (e.g. Klingberg et al., 2005). As WM appears to be weak in children with MID and because WM is so important for the acquisition of scholastic abilities, we developed a computerized visual WM training that was administered in seven schools for special education.

Finally, the empirical findings of the forgoing chapters will be summarized and discussed in Chapter 6 and it concludes with limitations of the present work and recommendations for future research.

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2

Verbal working memory in children with mild intellectual disabilities

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Abstract

Background: Previous research into working memory of individuals with intellectual disabilities (ID) has established clear deficits. The current study examined working memory in children with mild ID (IQ 55 – 85) within the framework of the Baddeley model, fractionating working memory into a central executive and two slave systems, the phonological loop and visuo-spatial sketchpad.

Method: Working memory was investigated in three groups: 50 children with mild ID (mean age 15 years 3 months), 25 chronological age-matched control children (mean age 15 years 3 months) and 25 mental age-matched control children (mean age 10 years 10 months). The groups were given multiple assessments of the phonological-loop and central-executive components.

Results: The results showed that the children with mild ID had an intact automatic rehearsal, but performed poorly on phonological-loop capacity and central-executive tests when compared with children matched for chronological age, while there were only minimal differences relative to the performance of the children matched for mental age.

Conclusions: This overall pattern of results is consistent with a developmental delay account of mild ID. The finding of a phonological-loop capacity deficit has important implications for the remedial training of children with mild ID.

Introduction

Several studies have shown that children with intellectual disabilities (ID) suffer from working-memory problems (Hulme & Mackenzie, 1992; Russell et al., 1996; Jarrold & Baddeley, 1997; Jarrold et al., 1999; Jarrold et al., 2000). Working memory is referred to as a system in which information can be temporarily stored and manipulated so as to support ongoing complex cognitive activities, such as reading and listening (Daneman & Carpenter, 1980; Baddeley, 1986). The complexity of this construct is illustrated by the working-memory model proposed by Baddeley (1986). This model consists of three components coined the 'phonological loop', the 'visuo-spatial sketchpad', and the 'central executive'. More recently, a fourth component, the 'episodic buffer', has been added (Baddeley, 2000). The phonological loop is conceived of as a mechanism storing verbal information on a temporarily basis. An automatic rehearsal process can activate the incoming information for the loop. The visuo-spatial sketchpad is a mechanism dedicated to the storage of dynamic and static visuo-spatial information for a short period. The phonological loop and the visuo-spatial sketchpad are considered slave systems that are coordinated by the central executive (CE). In addition to coordinating the slave systems, the CE is involved in retrieving and manipulating information from long-term memory and in the inhibition of prepotent responses. Finally, the episodic buffer is assumed to temporarily hold information from working memory and long-term memory in a multi-modal code (for a recent review, see Baddeley, 2003).

Studies applying the Baddeley model for examining working memory in individuals with ID have focused primarily on the phonological-loop component. These studies revealed that the capacity of the phonological loop is constrained in those individuals, both in adults (Numminen et al., 2001; Numminen et al., 2002) and in children (Russell et al., 1996; Jarrold & Baddeley, 1997; Henry, 2001; Henry & MacLean, 2002).

Furthermore, automatic rehearsal does not seem to take place in children with a mental age (MA) below 7 years (Jarrold et al., 2000). These findings have been interpreted to suggest that a deficient phonological loop contributes to the cognitive deficits seen in individuals with Down syndrome (Kanno & Ikeda, 2002), or at least contributes to their learning problems (e.g. Hulme & Mackenzie, 1992).

Unfortunately, little is known about the functioning of working memory in children with mild ID (MID; IQ ranging between 55 and 85). To the best of our knowledge, there are only three studies available applying the Baddeley model to working-memory function in children with MID. Henry (2001) observed a reduced phonological-loop capacity and for the children with an IQ in the lower range also poor performances on tasks used to assess the CE. Rosenquist et al. (2003) found that automatic rehearsal was deficient in children with MID. Finally, Henry and MacLean (2002) compared memory performance of children with MID with control children matched either on chronological age (CA) or on MA. The results show that children with MID performed consistently poorer on phonological-loop tests and on CE tests than children matched for CA. Compared with those matched for MA, the children with MID did worse on some of the phonological-loop and CE tests, but they performed equally well on other tests. This pattern of findings is difficult to interpret in terms of either a 'developmental-delay' hypothesis (i.e. cognitive processes in children with MID are the same as in typically developing children, but develop slower and reach asymptotic levels at an earlier age) or 'developmental-difference' account (i.e. children with MID are assumed to have a kind of structural deficit) of MID (for a review, see Bennett-Gates & Zigler, 1998).

The primary goal of the present study was to extend these findings by examining working-memory function in children with MID by presenting them multiple assessments of both the phonological-loop and CE components of the Baddeley model. Their performance will be compared with children matched for CA and MA, as in the Henry and MacLean (2002) study. Based on their study, it is assumed that children with MID will perform worse than the children matched for CA on all tasks. The most interesting comparison is between the children with MID and those matched for MA. This comparison should reveal whether the uneven pattern of phonological-loop findings observed by Henry and MacLean (2002) is robust. In addition, this comparison should decide between developmental-delay and developmental-difference accounts of MID at the level of the CE component of working memory.

Method

Participants

A total of 100 children participated in the study. Among them were 50 children with MID (38 boys, 12 girls), ranging in age from 13 to 17 years. These children attended a special school for mild intellectually disabled pupils. Half of these children lived at home, while the other half lived in special residentialcare settings. Children, diagnosed by psychiatrists, who also have attention deficit hyperactivity disorder, Pervasive Developmental Disorder Not Otherwise Specified (PDD-NOS), Down syndrome or other specific aetiologies were excluded. Two control groups were recruited: one

Table 1 Participants' details

	MID group (n = 50)		MA-matched group (n = 25)		CA-matched group (n = 25)	
	M	SD	M	SD	M	SD
Chronological age (months)	182.96	12.32	131.52	13.27	183.24	9.31
Mental age (Raven SPM)	128.26	23.48	131.96	17.59	179.99	19.78

CA, chronological age; MA, mental age; MID, mild intellectual disabilities; SPM, Standard Progressive Matrices.

group matched for CA and the other matched for MA. The CA-matched control group, recruited from a secondary school, consisted of 25 typically developing children (17 boys, 8 girls), who ranged in age from 13 to 16 years. The MA-matched control group, recruited from two primary schools, consisted of 25 typically developing children (17 boys, 8 girls), who ranged in age from 8 to 12 years. Scores on the Raven Standard Progressive Matrices (Raven et al., 1992) were used for matching (see also Numminen et al., 2002). Informed consent was obtained for all participants. Descriptive information of the participants is provided in Table 1. Group comparisons indicated that the MID group had a similar mean age as the group matched for CA (p = .92) and did not differ statistically on mean mental age from the group matched on MA (p = .53).

Materials and procedure

Phonological loop

Two tests were used to assess phonological-loop capacity: a *Digit span* and a *Non-word test*. In both tests, the participant has to immediately repeat digits or non-words in exactly the same order as presented. Both tests yield span scores, that is, the maximum amount of items that could be correctly repeated. Two tests both with two conditions were presented to allow for an examination of automatic rehearsal; a digit span test (with vs. without articulatory suppression) that provides an estimate of the automatic rehearsal ability, articulatory suppression requires the participants to repeat out loud the Dutch word 'de' (in English 'the') during the presentation of the digits; and a Non-word test (with monosyllabic vs. two syllabic words) to provide an estimate of the word length ability (Baddeley, 1986). All phonological-loop tests started with two items and, following correct repeats, one item is added until a maximum of 7 items.

Central executive

Four tests were administered to assess different aspects of executive functioning; dual-task management, information retrieval and manipulation, planning and inhibition. The test for *Dual-task* management was taken from Baddeley et al. (1997). Participants first performed a verbal span test and a visuo-spatial test, both in isolation, and then are required to perform both tests at the same time. The dual-task score is expressed relative to those obtained during single-task performance.

A *Word-fluency test* (Luteijn & Van der Ploeg, 1983) was used to assess the ability to retrieve and manipulate information from long-term memory. Two versions were administered: an 'animal' and a 'letter k' version. The child has to name as many words (animals and words starting with the letter 'k', respectively) as possible in 1 min. The score is the total amount of correct words in both versions.

Planning ability was assessed by administering the Wechsler Intelligence Scale for Children – Revised (WISC-R) subtest *Mazes* (De Bruyn et al., 1986).

Finally, *Digit generation* (DG) was used to assess the ability to inhibit prepotent responses (Towse & Mclachlan, 1999). This test requires participants to produce a number between 1 and 70, 70 times. This test generates multiple scores of randomness that can be calculated using the RGCalc scoring program (Towse & Neil, 1998). In addition to the commonly used scores, Evans' Random Number Generator Score (RNG), Redundancy (R), Turning Point Index (TPI), Phi Index 2gram (Phi2), Phi Index 7gram (Phi7) and Adjacent Value Score (A score), the number of omissions was registered (i.e. the number of times that the child was prompted to generate a number but failed to do so).

Participants were tested individually in a separate room at the school premises. All tests were completed in one session of 1 h. There were short intermissions between tests, and longer rests were given on demand.

Results

The results will be presented in three sections. The first section presents the outcomes of the betweengroup comparisons for the phonological-loop tests, and the second section presents the results that emerged from the CE tests. All scores were submitted to MANOVA, Bonferroni tests were used for multiple comparisons, and Tamhane's test was used when variance differed between groups (Tabachnick & Fidell, 2001). The third section presents the outcomes of a principal component analysis (PCA) of all test scores. The factor scores were then submitted to a MANOVA to assess group differences in the functioning of the phonological loop and CE. Preliminary analyses revealed that gender did not alter the results reported below ($F(1,97) = 1.26$, $p = .25$).

Phonological loop

Significant group effects were found for both the digit span scores and the non-word scores (see Table 2). Between-group analyses indicated that the performance of the children with MID on the digit span test was significantly worse compared with both the group matched for MA ($p < .05$) and the group matched for CA ($p < .01$). In addition, children with MID performed worse on the Non-word test than the group matched for CA ($p < .01$), but their scores did not differ significantly from those of the group matched for MA.

Two additional MANOVAs, including an additional within-subjects Task factor, were carried out to assess group differences in automatic rehearsal. In one MANOVA, the Task factor referred to word length (one vs. two syllables), and in the other referred to suppression (digit span vs. suppressed digit span). These analyses revealed significant effects of word length ($F(2,96) = 52.82$, $p < .01$) and articulatory suppression ($F(2,97) = 29.61$, $p < .01$). Both analyses failed to reveal significant group by task effects, indicating that all groups show similar articulatory suppression and word length effects, implying that the use of rehearsal is comparable.

Table 2 Mean performance and standard deviations of the groups on the phonological-loop tests and the central-executive tests

	MID group (n = 50)		MA-matched group (n = 25)		CA-matched group (n = 25)		
	M	SD	M	SD	M	SD	F (p)
Digit	4.16	.65	4.65	.71	5.36	1.04	19.88 (<.01)
Non-word	2.78	.58	3.09	.73	3.28	.68	5.44 (<.01)
Dual-task	94.69	11.46	97.25	11.20	97.34	10.09	.69 (.51)
Word fluency animal	17.86	4.92	20.64	5.65	22.12	6.33	5.56 (<.01)
Word fluency letter	9.08	4.01	11.36	4.59	11.80	4.03	4.52 (<.05)
Mazes	27.37	5.98	28.88	6.04	31.68	3.46	5.13 (<.01)
DG RNG	.31	.08	.28	.05	.25	.06	5.36 (<.01)
DG R	2.24	1.73	2.61	1.50	2.81	4.49	.41 (.64)
DG TPI	83.10	16.43	78.17	10.46	91.01	10.18	5.62 (<.01)
DG Phi2	−3.73	.41	−3.42	.87	−3.92	.59	4.36 (<.05)
DG Phi7	−2.04	1.65	−1.14	1.21	−2.59	1.24	6.36 (<.01)
DG A	33.44	14.04	29.87	6.96	24.29	7.98	5.48 (<.01)
DG O	3.33	4.55	4.64	5.23	.36	.99	7.05 (<.01)

CA, chronological age; DG, Digit generation; MA, mental age; MID, mild intellectual disabilities.

Central executive

Virtually, all CE test scores discriminated significantly between groups, with the exception of the dual-task test score and the DG test R score (see Table 2). Subsequent between-group comparisons indicated that the children with MID performed more poorly than the group matched for CA on word fluency animal ($p < .01$), word fluency letter ($p < .05$), mazes, DG RNG ($ps < .01$), DG TPI ($p < .05$), DG A and DG O ($ps < .01$), but not on DG Phi2 and DG Phi7 ($p > .05$). CE test scores did not differ significantly between the children with MID and the group matched for MA.

Principal component analysis

All test scores were submitted to a PCA with varimax rotation (Tabachnick & Fidell, 2001). The analysis yielded six factors explaining 71.1% of the total variance. The correlation coefficients of the test scores with the factor components are presented in Table 3.

The first factor explained 17.5% of the total variance and related to all four phonological-loop scores. Thus, this factor was coined 'phonological loop'. The second factor explained 14.5% of the total variance and related to the DG scores DG RNG, DG TPI and DG A. A similar factor has been obtained previously by Towse and co-workers, who dubbed this factor 'pre-potent associates' (Towse & Neil, 1998; Towse & Mclachlan, 1999). DG R and DG Phi2 loaded on the third factor explained 11.3% of the total variance. This factor was entitled 'production', as DG R reflects the ability to produce each digit with the same frequency and DG Phi2 eflects the ability to avoid specific response sets. The fourth factor was labeled 'memory retrieval and information

Table 3 Loadings for the principal components analysis of the phonological loop and the central executive tests measures

Test	Component 1	2	3	4	5	6
Digit	**.788**	.215	.105	.165	–.021	–.089
Non-word	**.736**	.295	–.097	.074	.127	–.196
Long non-word	**.820**	.083	.072	–.028	–.188	.100
Articulatory suppressed digit	**.762**	–.019	–.059	.262	.024	.139
DG RNG	–.137	**–.778**	.226	–.153	.042	.048
DG TPI	.274	**.696**	.342	–.083	–.240	–.101
DG A	–.156	**–.865**	–.171	–.158	–.139	–.071
DG R	–.030	–.072	**.839**	.183	.022	.129
DG Phi2	–.042	–.156	**–.832**	.137	.039	.100
Word fluency animal	.079	.117	.038	**.823**	–.168	–.037
Word fluency letter	.273	.097	–.024	**.688**	.081	–.071
Mazes	–.026	.312	–.207	.112	**–.655**	.186
DG Phi7	–.095	.221	–.112	.202	**.724**	.175
DG O	–.047	–.032	–.094	–.409	**.614**	.043
Dual-task	.016	–.026	.023	–.103	.042	**.939**

DG, Digit generation. Bold text indicates factor loadings > .6.

Table 4 Mean principle components analysis scores for each group

Component	MID group (n = 50) M	SD	MA-matched group (n = 25) M	SD	CA-matched group (n = 25) M	SD	F (p)
1 Phonological loop	–.35	.76	–.04	.82	.75	1.20	12.67 (<.01)
2 Prepotent associates	–.18	1.22	–.01	.58	.37	.74	2.58 (.08)
3 Production	.05	.59	–.32	.94	.22	1.53	1.96 (.15)
4 Memory RIM	–.30	.87	.33	1.13	.28	.95	4.65 (<.01)
5 Planning	.04	1.08	.53	.86	–.62	.56	8.28 (<.01)
6 Coordination	–.20	.99	.21	1.02	.19	.95	2.06 (.13)

CA, chronological age; MA, mental age; MID, mild intellectual disabilities; RIM, retrieval and information manipulation.

manipulation', as both word fluency tasks loaded on this factor explained 10.6% of the total variance. The maze score and the last two scores of DG, DG Phi7 and DG O, loaded on the fifth factor, explained 10.0%. This factor was named 'planning'. Finally, the dual-task test loaded on the sixth factor called 'coordination', explained 7.2% of the total variance.

The outcomes of the MANOVA are presented in Table 4. It can be seen that the score on 'memory retrieval and information manipulation' (factor 4) was lower for the children with MID compared with the group matched for MA (p < .05). The scores of the children with MID were lower than the CA group on the factors ‘phonological loop’ (factor 1, $p < .01$), ‘memory retrieval and information manipulation’ (factor 4, $p < .05$) and ‘planning’ (factor 5, $p < .01$).

Discussion

This study set out to assess working memory in children with MID within the context of the Baddeley (1986) model. The current focus was twofold. First, participants were presented with a battery of tests to assess the potential contributions of the phonological loop and CE in providing an account of the alleged deficiencies in working memory of individuals with MID. Second, the performance of the children with MID was compared with two control groups, one matched for MA and the other for CA, to assess whether the alleged deficiencies of working memory refer to a structural defect vs. a developmental delay. Most of the test scores revealed that children with MID performed as well as the children matched for MA, ruling out a developmental-difference account of the working-memory deficits. The children matched for CA outperformed the children with MID on most phonological-loop and CE tests. Overall, the current pattern of results is compatible with the developmental-delay hypothesis of ID.

More specifically, the children with MID did show the word length and articulatory-suppression effects, but on the tests tapping phonological-loop capacity, they performed even more poorly than the group matched for MA. This differentiated pattern of results suggests that the children with MID are deficient in phonological storage, but their automatic rehearsal seems to be intact. Although the results of the PCA must be interpreted with caution, given the modest sample size, the scores of the ‘phonological loop’ factor, that emerged from this analysis, discriminated significantly between the children with MID and their CA-matched controls. This finding is consistent with the ID literature reporting recurrent phonological-loop deficits in individuals with mild (Henry, 2001; Henry & MacLean, 2002) or severe (Jarrold & Baddeley, 1997; Jarrold et al., 2000) ID.

The results obtained from the executive-function tests indicated that, relative to age-matched controls, the children with MID performed more poorly on all tests with the exception of the dual-task test. The dual-task test, assessing the ability to direct and allocate attention, has been used widely to assess the functioning of the CE (e.g. Baddeley & Logie, 1999). Possibly, the current version of the dual-task test was not sufficiently effortful to qualify as a valid test of the CE (see also Bull & Scerif, 2001; Holtzer et al., 2004). The results that emerged from the PCA deviated from the above pattern, in that the factor ‘prepotent associates’, associated with the RNG, TPI and A scores, failed to distinguish between groups. By contrast, the factors ‘memory retrieval and information manipulation’, associated with the word fluency tests, and ‘planning’, associated with the maze test and two DG scores (DG Phi7 and DG O), discriminated significantly between the children with MID and their CA-matched controls. This differential pattern of findings is important for at least three reasons. First, the finding that word fluency test and the maze test loaded on different factors contributes to the literature supporting the fractionated nature of executive function (e.g. Miyake et al., 2000). Second, the finding that the factor ‘pre-potent associates’ failed to discriminate between groups suggests that the ability to inhibit is intact in children with MID. This preliminary conclusion should be assessed in future research employing a range of inhibition tasks, as the pertinent literature suggests that the ability to inhibit may comprise various components (e.g. Nigg, 2000; Huizinga, Dolan, & Van der Molen, 2006). Third, the finding that the factor 'memory retrieval and information manipulation' did discriminate between children with MID and the group matched for CA indicates that the ability to retrieve information from long-term memory and holding this information in memory is compromised in children with MID. Although the modest group size precludes strong conclusions, the observation that the scores of children with MID on this factor were even worse than those of the children matched for MA may point in a structural memory deficit. This possibility should be pursued in future work.

In conclusion, the current pattern of findings demonstrates that children with MID have multiple working-memory deficits. Within the context of the Baddeley (1986) model of working memory, the data present evidence to suggest that the storage of the phonological loop is constrained while the ability to rehearse seems to be intact. In addition, the tests used to assess the integrity of the CE control of working memory indicate that children with MID perform more poorly than the group of CA-matched children. The majority of the current findings are consistent with a developmental-delay account of mild ID. Following the proponents of the developmental-delay hypothesis, this pattern of results indicates that working memory of children with MID has a similar structure compared to typically developing children; there are no particular strengths or weaknesses (e.g. Bennett-Gates & Zigler, 1998). This conclusion must be qualified by two findings. That is, the scores on the memory factor and the performance on the phonological storage tests discriminated between children with MID and MA-matched controls. Both findings point to structural deficits in working memory of children with MID. Although the PCA finding must be interpreted with caution given the modest sample size, the apparent limitation of the phonological store may have important implications for training and education. In case of a reduced capacity of the phonological store in children with MID, then there may be little, if anything, to improve their memory function. These children may be best served by removing the need to rely on verbal short-term memory and, instead, presenting them with visual rather than verbal information (cf. Jarrold et al., 1999).

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3

Memory profiles in children with mild intellectual disabilities: Strenghts and weaknesses

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Abstract

Strengths and weaknesses in short-term memory (STM) and working memory (WM) were identified in children with mild intellectual disabilities (MID) by comparing their performance to typically developing children matched on chronological age (CA children) and to younger typically developing children with similar mental capacities (MA children). Children with MID performed less well on all measures compared to the CA children. Relative to the MA children, especially verbal WM was weak. Subsequent analyses yielded distinct MID subgroups each with specific memory strengths and weaknesses. These findings hold implications for the demands imposed on children with MID in education and daily life.

Introduction

Working memory (WM) deficits are known to exist in children and adults with moderate or severe intellectual disability (IQ below 55; see for a recent review Gathercole & Alloway, 2006). The literature on WM functioning in children with mild intellectual disabilities (MID; IQ 55 – 85), however, is relatively scant.[3] The aim of the present study is to identify WM strengths and weaknesses in children with MID and to explore whether subgroups exist with unique WM profiles within this heterogeneous population.

Working memory, which refers to the ability to temporarily store and manipulate information simultaneously (Baddeley, 1986), has been studied extensively during the past decennia (Jarrold & Towse, 2006). WM is considered a central construct in cognitive psychology (Cowan, 1999; Engle, Kane, & Tuholski, 1999; Shah & Miyake, 1999) and plays an important role in scholastic activities, including language comprehension (e.g. Daneman & Merikle, 1996) and arithmetics (e.g. Bull & Scerif, 2001). WM should be differentiated from short-term memory (STM) as WM involves both the active maintenance of verbal or visuo-spatial information (respectively, verbal STM and visuo-spatial STM) and at the same time the manipulation of information. Besides a conceptual difference, performance on STM and WM tasks relies on different neurophysiological processes in the brain. This is illustrated by the activation of the ventrolateral prefrontal cortex when STM tasks are carried out versus the activation of the mid-dorsolateral prefrontal cortex when WM tasks are being performed (e.g. Crone, Wendelken, Donohue, Van Leijenhorst, & Bunge, 2006).

Verbal STM is usually indexed by the number of items (digits or nonwords) that are reproduced in the same order as they were presented (Baddeley, 1986). An example of a visual STM test is the Corsi in which three-dimensional blocks have to be tapped in the same order as was shown (Baron, 2004). Verbal WM can be assessed by using Listening Recall (Pickering & Gathercole, 2001), in which people have to decide if a

[3] In this study we adopted the 55 to 85 IQ range for mild intellectual disabilities. This IQ range is used in Dutch governmental policy for special education and special services rather than the DSM-IV-TR (American Psychological Association, 2000) classifications for mild mental retardation (IQ 50 – 70) or borderline intellectual functioning (IQ 70 – 85).

sentence is true or false (e.g. 'pigs drive cars'), and at the same time have to remember the last word ('cars'). Visual WM, finally, can be examined using the Odd-One-Out test (Henry, 2001; adapted from Hitch and McAuley, 1991). This test presents three symbols, one of which is slightly different, and the participant has to decide which one is different while at the same time remembering the position of the odd-one-out.

Assessment of performance of children with intellectual disabilities usually involves a comparison to typically developing children of the same chronological age (CA) or to younger typically developing children having the same mental age (MA). MA can either be calculated or derived from raw scores on intelligence tests.[4] When children with intellectual disabilities perform less well than CA control children, it is assumed that they show a developmental delay. When they also perform less well than MA control children, it is assumed that they have a structural deficit (Bennett-Gates & Zigler, 1998).

Several studies have focused on WM and STM functioning in individuals with specific developmental disorders, including Down syndrome (e.g. Jarrold, Baddeley, & Hewes, 2000; Lanfranchi, Cornoldi, & Vianello, 2004) or Williams syndrome (e.g. Devenny, Krinsky-McHale, Kittler, Flory, Jenkins, & Brown, 2004). Reviewing this literature, Gathercole and Alloway (2006) discussed the patterns of specific strengths and weaknesses characterizing different populations with neurodevelopmental disorders. Individuals with Down syndrome, for example, consistently show a verbal STM deficit while their visuo-spatial STM is relatively intact. In contrast, individuals with Williams syndrome show visuo-spatial STM deficits, while their verbal STM is relatively intact (Gathercole & Alloway, 2006).

To date, studies of WM functioning in individuals with developmental disorders of non-specific origin focused primarily on persons with moderate to severe intellectual disabilities (i.e., mean IQ scores below 55; e.g. Bayliss, Jarrold, Baddeley, & Leigh, 2005; Henry & MacLean, 2002). As indicated above, studies examining WM functioning in children with MID are relatively rare. This is rather unfortunate, as children with MID represent the largest group within the total population of disabled children. An international review indicated that the prevalence of children with an IQ score between 50 and 70 is estimated to be about 3% compared to 0.4% for children with an IQ score below 50 (Roeleveld, Zielhuis, & Gabreëls, 1998).

To the best of our knowledge, only three studies examined WM functioning in children with an IQ score between 55 and 85. Henry (2001) compared a group of children with an IQ score between 70 and 85 and a group of children with an IQ score between 55 and 70 to a typically developing CA control group on a variety of tests measuring STM (Word Recall, Digit Recall, Spatial span, Pattern span) and WM (Listening Recall, Backward Digit Recall, Odd-One-Out test). The group in the lower IQ range showed delays on all the administered STM and WM tasks compared to the CA group. The group in the higher IQ range showed delays on verbal STM tasks compared to the

[4] Mental age = (IQ score x chronological age)/100. The chronological age at which the mean raw score of a group of people with intellectual disabilities indicates an IQ score of 100 is the mental age.

control group, but their visuo-spatial STM and verbal WM appeared to be intact. A recent study, reported by Hasselhorn and Mähler (2007), indicated that children in the 55 to 88 IQ range are able to hold as many words in verbal STM, measured with Nonword Recall, as children in a MA control group but less than children in a CA control group. Thus the results that emerged from these two studies suggests a developmental delay rather than a structural deficit in verbal STM of individuals with MID. This conclusion is in line with the results of a previous study (Van der Molen, Van Luit, Jongmans, & Van der Molen, 2007). This study showed that children ranging in IQ score between 55 and 85 performed worse on all verbal STM (Digit Recall, Nonword Recall) and central executive tasks (not WM tasks; Word fluency, Mazes, Digit Generation) compared to a CA group but only worse on Digit Recall and Word fluency compared to a MA group.

On the basis of these three studies, it seems that STM is weak in children with MID compared to CA children. The results regarding WM are less clear. Moreover, it is evident that strong conclusions regarding mnemonic functioning of children with MID cannot be drawn on the basis of only three studies. Thus the goal of the current study is to assess mnemonic functioning of children with MID, chronological age-matched peers and mental age-matched children across a range of memory tasks, including verbal and visuo-spatial WM and STM tasks. This assessment should reveal whether the alleged mnemonic dysfunction of children with MID is global (i.e. depressed scores on all tasks) or specific (i.e. some mnemonic functions are intact while others are deficient). Moreover, children with MID form a heterogeneous group as their lowered IQ score may originate from organic or familial factors, or both (Bennett-Gates & Zigler, 1998). Therefore, it would be interesting to explore whether meaningful subgroups can be detected within this population. Some children might be typified by an overall depression of scores on the memory task battery while others may show specific weaknesses or strengths. Obviously, sub-typing is of crucial importance to parenting and educational strategies tailored to the individual needs of children with MID.

Methods

Participants

A total of 65 children with MID ranging in age from 13 to 17 years and attending special schools for mild intellectually disabled pupils were available for this study. Children classified by psychiatrists based on the DSM-IV-TR (American Psychiatric Association, 2000) as having Attention Deficit/Hyperactive Disorder (ADHD, n = 14) or an Autism Spectrum Disorder (ASD, n = 1) were excluded as these psychiatric problems are known to be associated with specific WM strengths and weaknesses (Gathercole & Alloway, 2006), which might influence the results. In addition, one child was excluded because he was taking antipsychotic medication. This left a total sample of 49 children (55% boys) with MID to be included in this study of whom 15 children lived in residential care, the other 34 lived with their families. Two control groups were recruited, one group matched for chronological age (CA) and another group matched for mental age (MA; mental age was calculated by (TIQ × age)/100). The CA group consisted of 39 typically developing children (44% boys) who ranged in age from 13

Table 1 Descriptive characteristics of the participants

	MID group (n = 49)		CA group (n = 39)		MA group (n = 29)	
Component	M	SD	M	SD	M	SD
VIQ	68.6	9.04	98.6	7.49	100.5	9.02
PIQ	71.9	9.86	98.5	18.82	97.7	11.44
CA (in months)	181.5	11.83	183.0	5.74	125.5	10.66
MA (in months)	123.2	14.89	182.6	13.80	124.2	15.70
TRF	59.5	9.83	45.0	7.46	44.4	8.65

VIQ, verbal intelligence quotient; PIQ, performance intelligence quotient; CA, chronological age; MA, mental age; TRF, Teacher Report Form total score.

to 16 years. This group was recruited from three regular secondary schools. The MA group consisted of 29 typically developing children (38% boys) ranging in age from 8 to 12 years. This group was recruited from two regular primary schools. Children with known psychiatric problems were excluded from both control groups.

Informed consent was obtained for every participant. All participants had normal or corrected vision and were reported to be healthy; none of them were taking medication. Ethnicity and social economical status were comparable across the three groups. All children were born in The Netherlands. Descriptive information of the participants is provided in Table 1. To obtain information on IQ score and mental age of the children, we administered the complete Dutch version of the WISC-III (Kort et al., 2005). Group comparisons indicated that the group with MID did not differ in age from the group matched for CA ($t(1,86) = .74$, $p = .46$) nor in mental age for the group matched for MA ($t(1,76) = .28$, $p = .78$). Behavioral problems were assessed with the Teacher Report Form (TRF; Achenbach, 1991). ANOVA revealed a significant difference between the MID group and the MA group ($F(1,69) = 44.5$, $p < .001$) and between the MID group and the CA group ($F(1,71) = 46.3$, $p < .001$). This is line with recurrent observations showing that behavioural problems are more frequent in individuals with intellectual disabilities than in typically developing persons (e.g. Dekker, Koot, Van der Ende, & Verhulst, 2002). Analysis revealed furthermore that, like in typically developing children (e.g. Alloway, Gathercole, & Pickering, 2006), gender did not affect any of the measures of the test battery ($F(1, 41) = 1.57$, $p = .17$).

Measures

The test battery consisted of two verbal and two visuo-spatial STM tasks, and two verbal and one visuo-spatial WM tasks.

Verbal STM

Digit Recall (recall of spoken lists of digits) and *Nonword Recall* (recall of spoken lists of monosyllabic Dutch sounding nonwords) were used to assess verbal STM (Baddeley, 1986). Both tasks consisted of sequences comprising two up to six items. Items were presented orally with a rate of one item per second. Three trials were available for every sequence but when two trials were repeated correctly, the third was omitted but awarded by one point. Scores for each task could vary between 0 and 18.

Visuo-spatial STM

The *Corsi test* was administered to assess the dynamic aspect of visuo-spatial STM. The task instructions were adopted from Block Recall, a subtest of the WMTB-C (Pickering & Gathercole, 2001). The experimenter tapped a sequence of three-dimensional blocks, arranged on a board in front of the child, which the child had to repeat in the same order. The task started with one block up to sequences of nine blocks. For every sequence, six trials were available but the next sequence was presented upon four correct items. Correctly made items were awarded by one point each. Scores could vary from 0 to 54.

To assess the static aspect of visuo-spatial STM, the *Visual Patterns test* (Della Sala, Gray, Baddeley, & Wilson, 1997) was administered. Here the child was shown a matrix depicted on a stimulus card, varying in configuration from 2×2 to 5×6 squares. In each matrix, some of the squares were marked. After inspecting a stimulus card for 3 seconds, the child had to indicate the marked squares in the blank grid on the response sheet. There were three stimulus cards for each of the fourteen difficulty levels. Testing continued until the child failed to recall correctly any of the three matrixes at a given level of difficulty. Scores could vary from 0 to 42.

Verbal WM

Two tasks were used to assess verbal WM. *Backward Digit Recall* required the child to reproduce spoken lists of digits, but in the reverse order. Procedure and scoring for this task was similar to Digit Recall. The second task, *Listening Recall* (Pickering & Gathercole, 2001), required the child to listen to simple statements and to determine whether they were true or false, while at the same time remembering the last word of each statement. Following each trial, these last words were to be repeated in the same order as presented. Trials started with one sentence, up to a maximum of six. Six trials were available for each sequence and the next sequence was presented upon four correct trials. Every correctly made item was rewarded with one point. Scores could vary from 0 to 36.

Visuo-spatial WM

Only one test of visuo-spatial WM was found suitable for children, the *Odd-One-Out test* (Henry, 2001, adapted from Hitch & McAuley, 1991). In this test, each trial contained a sequence of three indefinable figures of which two were similar and one was slightly different: the odd-one-out. The child had to decide which one is the odd-one-out and remember its location. Following each trial, the child had to point to the locations of the odd-one-outs in the same sequence as presented. Trials started with two sequences, up to a maximum of six. Three trials were available for each sequence length and the next sequence length was presented upon two correct trials. Correctly made trials were awarded by one point each. Scores could vary from 0 to 15.

Data analysis

To explore group differences, all scores were submitted to MANOVA. Data were first explored to see if assumptions were met. Indeed, data normality was satisfied. It is well known that STM and WM tests correlate moderate to high (e.g. Bayliss, Jarrold, Baddeley, & Gunn, 2005). This does not have to influence the results of MANOVA, although correlations between dependent variables diminish its power (Tabachnick & Fidell, 2007). In addition, memory performances of the groups were analyzed by separate MANCOVA's with performance IQ score and verbal IQ score to see if possible differences still hold when correcting for IQ scores. Furthermore, the total score of the TRF was taken as covariate, as behavioral problems were far more present within the MID group than in both control groups.

Finally, to explore whether identifiable subgroups were present among children with MID, two separate hierarchical cluster analyses were conducted with Ward´s linkage method (Ward, 1963); one with *Z* scores based on the CA group and the other based on the MA group. To obtain interpretable profiles, the analyses were based on mean *Z* scores per memory aspect which resulted in a *Z* score verbal STM (mean *Z* score from Digit Recall and Nonword Recall), a *Z* score verbal WM (mean *Z* score Listening Recall and Backward Digit), a *Z* score visual STM (mean *Z* score Visual Patterns test and Corsi test) and a *Z* score visual WM (*Z* score Odd-One-Out).

Results

Table 2 shows means and standard deviations for each of the scores, group effects and effect sizes. It can be seen that the effect sizes for the MID versus CA contrasts are sizeable, ranging from .98 to 1.59. Effect sizes are considerably lower for the MID vs. MA contrasts.

Verbal short-term memory

MANOVA revealed significant group effects on Digit Recall and Nonword Recall. Post-hoc analysis indicated that for Digit Recall, the MID and MA groups performed equally well, but both groups did worse than the CA group (MID group $F(1,86) = 56.04$, $p < .001$; MA group $F(1,66) = 27.89$, $p < .001$). The post-hoc analysis for Nonword Recall showed that the MID group performed less well than the MA and CA groups ($F(1,76) = 6.40$, $p < .01$ and $F(1,86) = 21.30$, $p < .001$, respectively).

Visuo-spatial short-term memory

For both the Corsi and the Visual Patterns test, MANOVA revealed significant group effects. Post-hoc analysis indicated that on the Corsi test the MID group performed worse than the MA group ($F(1,76) = 8.22$, $p < .01$) and the CA group ($F(1,86) = 38.45$, $p < .001$). On the Visual patterns test, however, the MID group performed equally well as the MA group, but worse than the CA group (MID group $F(1,86) = 36.10$, $p < .001$.

Verbal working memory

MANOVA revealed that the MID group performed worse than the MA group on both Listening Recall and Backward Digit Recall (respectively $F(1,76) = 8.12$, $p < .01$; $F(1,76) = 8.52$, $p < .01$) and CA group (respectively $F(1,86) = 25.81$, $p < .00$; $F(1,86) = 38.36$, $p < .001$). To assure that the lower scores were not related to an impaired verbal STM, we performed separate MANCOVAs with respectively Digit Recall and Nonword Recall as covariates. In both cases, the significant group effects remained for both verbal WM tests ($p < .001$).

Table 2 Performance of the groups on the mnemonic task battery

	MID group (n = 49)		CA group (n = 39)		MA group (n = 29)			
	M	SD	M	SD	M	SD	F (p)	d CA/MA
Verbal STM								
Digit Recall	10.5	2.39	14.3	2.20	11.3	2.38	29.17 (.00)	1.59/.31
Nonword Recall	5.3	1.92	7.2	2.00	6.4	1.80	11.26 (.00)	.98/.59
Visuo-spatial STM								
Corsi	25.3	3.19	30.3	4.31	27.3	2.39	22.52 (.00)	1.32/.66
Visual Patterns	15.5	3.46	20.3	3.88	14.7	3.76	24.78 (.00)	1.28/.24
Verbal WM								
Listening Recall	12.7	3.48	16.2	2.92	14.8	2.47	14.87 (.00)	1.08/.66
Backward Digit Recall	5.6	1.91	8.6	2.67	6.9	1.90	20.74 (.00)	1.32/.68
Visuo-spatial WM								
Odd-One-Out	8.3	3.33	11.3	2.64	8.7	4.01	9.62 (.00)	.97/.12

(Cohen´s) *d*, effect size (.1 – .3 small, .3 – .5 moderate, .5 – 1.0 large; Cohen, 1988).

Visuo-spatial working memory

Analysis of the Odd-One-Out test scores showed significant group effects. The MID group performed less well on this test than the CA group (MID group $F(1,86) = 20.91$, $p < .001$). No other group differences were observed. Separate MANCOVAs were performed with respectively the Visual Patterns test and the Corsi test as covariates to assure that the lower score on the Odd-One-Out test was not related to an impaired visual STM. In both cases, the significant group effect remained (respectively $p < .05$ and $p < .01$).

In sum, the MID group performed less well on all tests when compared to the CA control group. Compared to the MA group, the MID group scored lower on Nonword Recall, the Corsi, Listening Recall, and on Backward Digit recall.[5,6]

Memory, IQ score and behavioral problems

MANCOVA with verbal IQ score as a covariate revealed a significant effect of group $F(2,107) = 7.39$, $p < .001$. Likewise, an analysis using performance IQ score as a covariate revealed a significant effect of group, $F(2,107) = 7.96$, $p < .001$. Post-hoc analyses with verbal IQ as a covariate revealed a better performance of the MID group compared

[5] In MANCOVA with mental age and chronological age as co-variates did not alter the results obtained with MANOVA.

[6] An additional MANOVA was carried out on all tasks with two groups as independent factor: MID children with an IQ score in the range 55 – 70, and MID children with an IQ score in the range 71 – 85. The MID children in the higher IQ range did better than the MID children in the lower range on two of the seven tasks, Nonword Recall and the Odd-One-Out, both $p < .01$.

Table 3 Descriptive characteristics of the cluster groups

	Cluster groups relative to CA group						Cluster groups relative to MA group					
	A (n = 16)		B (n = 26)		C (n = 7)		1 (n = 7)		2 (n = 34)		3 (n = 8)	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
VIQ	73.6	8.62	64.8	7.64	71.7	9.18	72.7	5.88	68.0	9.07	67.3	11.12
PIQ	69.7	13.76	73.5	7.53	71.0	6.58	74.9	8.37	71.7	10.86	70.4	6.23
CA (months)	178.5	9.66	183.6	11.18	180.1	17.88	172.0	10.00	182.7	10.79	184.4	14.77
MA (months)	126.1	16.80	121.5	14.66	123.2	11.72	123.1	16.18	123.7	15.51	121.4	12.53
TRF	53.4	9.39	62.5	8.04	62.3	11.83	55.0	11.66	59.8	9.32	61.7	10.77

VIQ, Verbal Intelligence Quotient; PIQ, Performance Intelligence Quotient; CA, Chronological Age; MA, Mental Age; TRF, Teacher Report Form total scores.

to the MA group on Digit Recall ($F(1,69) = 4.42$, $p < .05$) and on the Odd-One-Out ($F(1,69) = 14.15$, $p < .001$), while the MID group did worse compared to the CA group on Digit Recall ($F(1,79) = 3.92$, $p = .05$), Backward Digit Recall ($F(1,79) = 8.21$, $p < .01$), on the Corsi test ($F(1,79) = 4.32$, $p < .05$) and on the Visual Patterns test ($F(1,79) = 12.31$, $p = .001$). Finally, when taking performance IQ score as covariate, post-hoc testing indicated a lower score for the MID group on Backward Digit Recall compared to the MA group ($F(1,69) = 6.29$, $p < .05$), and compared to the CA group a lower score on all tests ($F(1,79) = 27.39$ for Digit Recall, 8.51 for Nonword recall, 9.19 for Listening Recall, 15.62 for Backward Digit Recall, 11.48 for the Corsi test, 22.71 for the Visual Patterns test and 12.75 for the Odd-One-Out, all with $p < .01$).

MANCOVA with the TRF total score as a covariate showed a significant effect of group, $F(2,92) = 8.04$, $p < .001$. Post hoc analyses revealed a significant higher score for the MA group than for the MID group, $F(1,63) = 3.57$, $p < .01$, on Listening Recall ($p < .01$) and on Backward Digit recall ($p < .001$), while the Corsi test reached significance ($p = .06$). The CA group did better than the MID group, $F(1,65 = 12.71$, $p < .001$) on all tests; Digit Recall ($p < .001$), Nonword Recall ($p < .05$), Listening Recall ($p < .001$), Backward Digit recall ($p < .001$), Visual Patterns test ($p < .001$), the Corsi test ($p < .05$) and the Odd-One-Out ($p < .05$).

Summing up, when correcting for verbal IQ score, the MID group does better than the MA group on Digit Recall and on the Odd-One-Out. However, the MID group still does less well than the CA group on Digit Recall, Backward Digit Recall, the Corsi test and on the Visual Patterns test. When correcting for performance IQ score, the MID group does less well than the MA group on Backward Digit Recall and less well on all tests compared to the CA group. When correcting for behavioral problems, indexed by the TRF total score, the MID group does worse than the MA group on Listening Recall and Backward Digit recall, and worse than the CA group on all STM and WM tests.

Profiles

Hierarchical cluster analysis relative to the CA group (in Z scores) resulted in three distinct clusters, respectively cluster group A, B, and C (see Table 3 for the descriptives of all clusters). Cluster A (n = 16; 3 girls, 13 boys) was characterized by an average score on Visual WM (Z = .2) and low scores on the other memory aspects (Zs vary between –.9 and –1.3). Cluster B (n = 26; 12 girls, 14 boys) was characterized by low scores overall (Zs vary between –1.2 and –2.0) and cluster C (n = 7; 7 girls) by average scores on Verbal STM (Z = –.1) and Verbal WM (Z = .2) and low scores on Visual STM (Z = –1.6) and Visual WM (Z = –1.0). Subsequent analyses revealed no differences between the cluster groups on age and performance IQ score, but the cluster groups did differ in behavioral problems, $F(2,36) = 4.64$, $p < .05$ and verbal IQ, $F(2,36) = 5.29$, $p < .01$. Post-hoc analyses indicated a lower TRF score for cluster A than for cluster B, $F(1,31) = 9.56$, $p < .01$ and a higher verbal IQ score for cluster A than cluster B, $F(1,31) = 10.53$, $p < .01$.

A similar analysis relative to the MA group also yielded three distinct clusters, respectively cluster group 1, 2, and 3. Cluster 1 (n = 7; 3 girls, 4 boys) showed average Z scores on Verbal STM and Verbal WM (respectively Z = .34 and Z = –.27) and above average Z scores on Visual STM and Visual WM (respectively Z = 1.14 and Z = 1.03). Cluster 2 (n = 34; 12 girls, 22 boys) exhibited low Z scores on Verbal STM, Verbal WM and Visual STM (Zs between –.85 and –.11) and an average score on Visual WM (Z = –.25). Finally, cluster 3 (n = 8; 7 girls, 1 boy,) showed an above average score on Verbal STM (Z = .45) and an average score on Verbal WM (Z = .04) and low scores on visual STM (Z = –1.3) and on Visual WM (Z = –.52). Subsequent analyses indicated that these three cluster groups did not differ on age, behavioral problems, performance IQ score and verbal IQ score.

Comparing clusters A, B and C versus clusters 1, 2 and 3 it appeared that there was considerable overlap (73.5%) as can be seen in Table 4. The largest group of children was assigned to both clusters B and 2. This group could be characterized in terms of an overall weak memory, even compared to the MA group, although visual WM was conform its mental age (relative to A-1 and C-3 children who show specific strengths, even compared to the CA control group). In addition, a substantial number of children were placed in of clusters A and 2. This group could be characterized in terms of their strong visual WM, even when compared to the CA control children, but all other memory aspects were inadequate.

In sum, in comparison with the CA control group, the three cluster groups A, B and C do generally worse on the four memory aspects. However, cluster A does as well on visual STM and cluster C on both verbal STM and verbal WM as the CA control group. Cluster B does not show such strengths. In addition, compared to the MA control group, the three cluster groups 1, 2, and 3 generally perform equally well on the four memory aspects. However, verbal WM is weak for cluster 1 and 2 compared to the MA control group. Cluster 2 and 3 show an additional weakness on visual STM. Most children were assigned to similar groups (A to 1, B to 2, etc.).

Table 4 Flow of participants from clusters A, B and C to 1, 2 and 3

Cluster	A	B	C	Total
1	**6**	0	1	7
2	10	**24**	0	34
3	0	2	**6**	8
Total	16	26	7	49

Discussion

This study, to our knowledge, is the first to investigate verbal and visuo-spatial STM and verbal and visuo-spatial WM in children with MID in relation to performance of both typically developing CA-matched children and MA-matched children. The results showed that the children with MID perform below the CA group on all administered STM and WM tasks. This finding is consistent with our own previous reported data (Van der Molen et al., 2007) and with performance of the lower IQ group (IQ score 55 – 70) in Henry's study (Henry, 2001).

The MID and MA groups differed in several, but not all, STM and WM aspects examined in this study. For verbal STM the MID group did equally well on Digit Recall, but worse on Nonword Recall in comparison with the MA group. Nonword Recall is generally regarded to be a better index of verbal STM than Digit Recall or a test in which existing words have to be repeated, because long-term knowledge cannot, or at least to a lesser extent, support remembering and reproducing nonwords (e.g. Baddeley, 2003; Gathercole, 1998) where it can in the case of digits or words. However, when correcting for behavioral problems, the difference on Nonword Recall disappeared. This is in line with the results of Hasselhorn and Mähler (2007) who did not find a difference between children with MID and a MA control group on Nonword Recall. Accordingly, these results suggest that adolescents with MID have a verbal STM in line with their mental age.

Visual STM showed a fractionated pattern of results, in that the MID group performed equally well as the MA children on the task tapping the static aspect of visuo-spatial STM (Visual Patterns test) whereas they did less well on the task measuring the dynamic or spatial aspect (Corsi test). Some studies examining the Corsi test suggest that it is not a 'pure' STM task, but also depends on executive functioning (e.g. Vandierendonck, Kemps, Fastame, & Szmalec, 2004). The impact of executive functioning on this task is especially noticeable among young children of about 6 years of age (Alloway et al., 2006). Moreover, Hambrick, Kane, and Engle (2005) consider spatial STM as being more dependent on executive functioning than verbal STM, regardless of the task used. Their interpretation is that verbal storage can rely on learned processes like rehearsal whereas visual information is generally more novel and therefore relies more on attention ability, in terms of Baddeley (1986): the central executive. Possibly, the executive demands of this task made the children with MID do less well compared to the younger typically developing children. Maybe, the Corsi task did not demand central executive functioning in the MA children, where it did so in the MID children.

In fact, the current results might indicate that spatial STM performance in MID children is comparable to that of 6 years old typically developing children (Alloway et al., 2006).

The children with MID performed worse on Backward Digit Recall and Listening Recall in comparison to the MA children. This finding suggests that storing and manipulating verbal information simultaneously is extremely difficult for children with MID. In contrast, performance on the Odd-One-Out task was adequate (compared to MA-matched children), suggesting a relatively intact visual WM. The latter finding is in keeping with the view that WM is domain specific (e.g. Shah & Miyake, 1996). It should be noted, however, that there is considerable support for the opposite view; that is, WM is domain general (e.g. Baddeley, 2003; Engle et al., 1999), not only for adults but also for children (e.g. Alloway et al., 2006). The apparent divergence between verbal and visual WM in children with MID might be taken to suggest that WM structure in MID children is different from typically developing children. On an alternative account, however, the Odd-One-Out task might be less taxing in children with MID than Listening Recall. Listening Recall requires the child to manipulate information (deciding if the sentence is true or false) and storing other information (the last word of each sentence) while the Odd-One-Out task requires manipulation of information (deciding which figure is the odd one out) which directs you automatically to the information that has to be stored (the position of the odd one out figure). In this regard, the Odd-One-Out task is less demanding which might explain why the children with MID did relatively well on this task. Thus, before accepting that children with MID have a different WM structure, future research should use one or more visual WM tasks that is equally demanding as Listening Recall like, for example, the recently developed Mr X. or Spatial span tests (Alloway & Gathercole, 2007). In addition, Listening Recall requires besides intact WM skills, also semantic decision making (true/false judgments). This ability on its own might have influenced the results, although the judgments are not very complex (e.g. 'people have ears', 'cows can fly'). In future research it would be interesting to take the semantic demands into account by asking the participant also to judge sentences without having to remember the last word. This would make it possible to show the relevance of semantic decision making within Listening Recall.

In line with the above comments on the Odd-One-Out and with the findings on the Corsi task (the MID group did worse on this task than the MA group probably because of the task's dependency on executive functioning for the first group) however, it follows that children with MID do have a general weak WM. A unified account of our results, then, suggests that children with MID have a relatively intact visual STM associated with a deficient verbal STM and a malfunctioning WM. Although the results did not change when correcting for age, probably because the age range was too small for each group, it is not said though, that children with MID are not able to progress on WM functioning with age because, at least in the typically developing population, WM develops until late in adolescence (around 17 years of age). In contrast, STM functioning reaches its ceiling at around 11 years of age (e.g. Conklin, Luciana, Hooper, & Yarger, 2007; Huizinga & Van der Molen, 2007).

When correcting for performance IQ, all MID test scores stayed significantly delayed compared to the CA control group, whereas correcting for verbal IQ, only on some tests statistically significant differences remained. This is not surprising given the dependency of all tests, including the visuo-spatial STM and WM tests on verbal reasoning (e.g. Archibald & Gathercole, 2006; Durand, Hulme, Larkin, & Snowling, 2005), hence, when correcting for verbal ability, most of the differences in scores between the MID group and control group disappear. Apparently, children with MID are somehow able to mask or compensate memory deficits by their acquired (verbal) abilities.

Finally, cluster analyses were performed to identify meaningful subgroups within the sample of children with MID. These children are generally simply labeled by their IQ score. However, this does no justice to the diversity in cognitive abilities these children show. The cluster analysis resulted in three clusters both when compared to the CA children and compared to the MA children. Mnemonic functioning compared to CA children showed a differentiated pattern. The first cluster (A) showed an overall memory delay associated with an intact visual WM. The second cluster (B) had low scores on virtually all tasks of our mnemonic task battery. In contrast, the third cluster (C) showed average performance on verbal STM and WM, while visual STM and WM were delayed. Cluster A had a higher verbal IQ score and less behavioral problems than cluster B. Cluster analyses in reference to the MA control group resulted in a different cluster classification. Cluster 1 showed a strong visual STM and WM, an average verbal STM and a somehow weaker verbal WM. Cluster 2 showed an average to weak visual STM and WM and a very weak verbal STM and WM. Finally, cluster 3 had average mnemonic functions except visual STM which was very weak. No differences in performal and verbal IQ score, age and behavioral problems were found between these three groups. Nearly 75% of the children were assigned to the same cluster groups compared to the CA and to the MA control groups, i.e. the children who were assigned to cluster A were also assigned to cluster 1, etc. The corresponding profiles were different though: these children exhibit a different memory profile when compared to the CA children, than when compared to the MA children. In essence, a weakness compared to the CA children, might be in fact a relatively normal ability compared to the MA children. Only the 10 children who changed from group A to group 2 show similar strengths and weaknesses independent of the control group with whom they are compared: a relatively weak verbal STM, verbal WM and visual STM, but average or strong on visual WM.

These cluster classifications show that although the groups of children with MID have generally comparable IQ scores, they do not have comparable memory skills. Future research should confirm the reliability and validity of the current sub-typing. For example, longitudinal assessment of the groups identified in the current study should reveal whether the differentiated patterns of strengths and weaknesses have implications for (future) learning. Given that WM is considered to be more important for scholastic activities than is STM (Towse & Cowan, 2005), children in cluster C and 3 are expected to have a higher learning potential. An observational study reported by Gathercole and colleagues showed that (4 and 5 years old) typically developing children with specific WM problems experience difficulties with, for example, writing sentences from memory (dictation) and carrying out numerical calculation abstracted from questions expressed in everyday language (Gathercole, Lamont, & Alloway, 2006). Likewise, the present findings seem to imply that children with MID require support and instruction, tailored to the specific profiles of memory weaknesses and strengths.

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4

Everyday memory and working memory in children with mild intellectual disabilities

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Abstract

Everyday memory and its relationship to working memory performance was investigated in children with mild intellectual disabilities and compared to typically developing children of the same age (CA) and younger typically developing children matched on mental age (MA). The results showed a delay on all memory measures for the children with mild intellectual disabilities compared to the CA control children. Compared to the MA control children, the children with mild intellectual disabilities performed similar on two of the four everyday memory measures and on three of the seven WM measures. Significant associations were found between everyday memory and working memory for the MA end MID children.

Introduction

Many activities in everyday life depend on remembering things for short periods of time, like a telephone number or the spelling of a name you never heard before, long enough to be able to write it down (Gathercole, 1999). In addition to short-term memory demands, everyday life requires active maintenance and processing of information, in essence, working memory processes (Baddeley, 1986; Engle, Kane, & Tuholski, 1999). This happens for example when one has to step out of a routine activity like driving to the dentist instead of the usual trip to work (Unsworth & Engle, 2007), or when somebody is explaining you the way how to drive to a shop in case you have never been there before.

Evidently, these so-called everyday memory (EM) activities are necessary for leading an independent life (Kazui et al., 2005). Defined this way it comes as no surprise that both adults and children for whom an age-appropriate autonomous life is not self-evident have been involved in studies on EM. Populations studied include, for example, adults suffering from Alzheimer (e.g. Clare, Wilson, Carter, Breen, Gosses, & Hodges, 2000), children with epilepsy (e.g. Kadis, Stollstorff, Elliott, Lach, & Smith, 2004) and children born prematurely (e.g. Briscoe, Gathercole, & Marlow, 2001). Several studies have been carried out on EM in people with intellectual disabilities (e.g. Numminen, Service, Ahonen, and Ruoppila, 2001). Understanding weak EM functioning in adults and children with intellectual disabilities is crucial to improve support at an individual level. Such support might enhance their ability to live their life as autonomous as possible, which is likely to result in a higher perceived quality of life (Lachapelle et al., 2005).

EM is mostly assessed by use of laboratory tests imitating EM situations. The Rivermead Behavioral Memory Test (RBMT; Wilson, Cockburn, & Baddeley, 1985) is probably the best known and most used. This test consists of 11 verbal, spatial and visual subtests, like remembering a short story, a route and recognizing a picture. Another way of assessing EM is asking the person, or important people around that person, how easy or difficult it is to remember things in everyday life (e.g. Kadis et al., 2004).

Studies on EM in people with intellectual disabilities mostly use the RBMT. Numminen et al. (2001), for example, compared adults with Down syndrome (mean age 42 years) to adults with disabilities of non-specific aetiology (mean age 51 years), matched on nonverbal intelligence (range IQ scores 35 – 70) on the RBMT. Quite unexpectedly, both groups performed similarly on the two RBMT indices. Martin, West, Cull, and Adams (2000) compared RBMT performances within a group of adults with intellectual disabilities (mean age 32 years, range IQ scores 55 – 75) and observed that these adults have particular difficulty with remembering a story while recognition of visual information is relatively easy for them.

To the best of our knowledge there are no studies available of EM functioning in children with intellectual disabilities. This is unfortunate as knowledge about their daily memory functioning could be useful in determining which support or training these children need inside and outside the classroom. In addition, such knowledge might provide guidelines on how to compensate possible shortcomings early in life. Thus, principal aim of the current study is to assess EM functioning in children with mild intellectual disabilities (MID). To be able to contrast their performance to that of children with a typical development, their scores will be compared to typically developing children matched on chronological age and to typically developing children matched on mental age. In line with Martin et al. (2000), we expect the children with MID to have particular problems with story recall, but less with recognizing pictures.

Although it is unknown what the EM strengths and weaknesses are from children with MID, relatively more is known about their short-term memory (STM) and working memory (WM) functioning. Recent studies indicate that children with MID perform poorly on tests measuring WM (Henry, 2001; Van der Molen, Van Luit, Jongmans, & Van der Molen, 2007; submitted), i.e. the ability to maintain and process information simultaneously (Baddeley, 1986). As mentioned before, WM is known to be important for the successful implementation of complex cognitive activities in everyday situations (Gathercole & Alloway, 2006; Logie, 1993). Hence, we expect that especially the EM tasks which are difficult for MID children, depend more on WM processes than tasks that are relatively easy for them. Therefore, the second aim of this study is to investigate the associations between EM and WM in children with MID and the two control groups.

Materials and method

Participants

A total of 104 children participated in the study including 39 children with MID (27 boys, 22 girls) ranging in age from 13 to 17 years. These 39 children attended special schools for mild intellectually disabled pupils. Their range in IQ score was between 55 and 75, a range that is used as a standard range by the American Association on Intellectual and Developmental Disabilities (formerly known as the American Association on Mental Retardation, Luckasson et al., 2002) for defining children with MID. Children diagnosed by psychiatrists as having Attention Deficit/Hyperactive Disorder, Pervasive Developmental Disorder-Not Otherwise Specified or other specific etiologies were excluded as these psychiatric problems are known to be associated with specific WM strengths and weaknesses (Gathercole & Alloway, 2006) which might influence the results.

Two control groups were recruited, one group matched for chronological age (CA) and another group matched for mental age (MA; mental age was calculated by (FSIQ x age)/100 and additional checks were made by comparing the total mean raw scores of the WISC-III for both groups). The CA group consisted of 39 typically developing children (17 boys, 22 girls) who ranged in age from 13 to 16 years. This group was recruited from three regular secondary schools. The MA group consisted of 26 typically developing children (10 boys, 16 girls) ranging in age from 9 to 12 years. This group was recruited from two regular primary schools. Informed consent was obtained for every participant.

All participants had normal or corrected vision and were reported to be healthy. Ethnicity and social economical status were comparable in all three groups. Descriptive information of the participants is provided in Table 1. To obtain information of IQ and mental age of the children, we administered the full Dutch version of the WISC-III (Kort et al., 2005). Group comparisons indicated that the group with MID did not differ in chronological age from the group matched for CA ($t(1,86) = .74$, $p = .46$) nor in mental age from the group matched for MA ($t(1,59) = .90$, $p = .37$). The MID and the MA group did not differ either on the total raw score of the WISC-III ($t(1,59) = 1.31$, $p = .20$). Analyses revealed that no gender differences were found in the complete group of children, $F(2,90) = 1.36$, $p = .17$. Therefore, these will not be considered further.

Procedure

All children were tested in a quiet room at their school. The WISC-III was administered during one session of about 75 minutes and the memory tasks during a second session of about 60 minutes, both within one day, with at least 1.5 h interval.

Measures

One test and two questionnaires assessed memory functioning in everyday life and seven tests were administered to assess short-term memory (STM) and working memory (WM).

Table 1 Participants' details

	MID (n = 39)		CA-CON (n = 39)		MA-CON (n = 26)	
	M	SD	M	SD	M	SD
Full scale IQ score	65.0	5.29	99.8	7.60	97.1	7.86
Chronological age (months)	181.5	11.95	183.0	5.74	124.4	10.78
Mental age (Raven SPM)	118.1	11.12	182.6	13.80	120.7	12.23

CA, chronological age; MA, mental age; MID, mild intellectual disabilities; SPM, Standard Progressive Matrices.

Everyday memory

The *Rivermead Behavioural Memory Test* (RBMT; Wilson et al., 1985; Dutch version by Van Balen & Groot Zwaaftink, 1987) assesses memory problems in everyday life. It presents the participant with analogies for everyday situations in which memory is used and is said to be suitable also for administering in populations with MID (Martin et al., 2000). The RBMT contains eleven verbal, visual and spatial subtests. In this study 'RBMT Screening', the standardized total score is presented. This is the general index of memory in everyday life. However, to obtain more detailed information and to allow comparisons to scores on the working memory tasks we present three additional raw subscores as well. RBMT Story recall is a subtest in which a story has to be repeated both immediately after presentation and 20 minutes later. Furthermore, scores on the RBMT subtests Visual recognition and Route recall were included. RBMT Visual recognition consists of two subtests in which illustrations and photos of faces have to be recognized. RBMT Route recall (immediate and delayed) requires the child to walk a short route shown by the experimenter. The child has to pick up an envelope along the route and, later on, put it down on a specific spot. This task is done immediately following the example of the experimenter and following a delay of about 15 minutes.

The *Everyday Memory Questionnaire for children, child version* (EMQ-child; Van Leeuwen, 1990) consists of nine questions about the child's memory functioning in everyday life, like remembering what you have read or what you did that day. Each question consists of two stages that are recommended for people with intellectual disabilities (Finlay & Lyons, 2001). The child first decides if he belongs to children who can remember something well (e.g. a song or a shopping list) or if he belongs to children who are not able to remember things well. Then the child decides if he belongs very much to the chosen group, or only a bit. If he belongs very much to the group who remembers not well, 3 points are given, if he belongs just a bit to that group, 2 points are given. When the child belongs a bit to the group who can remember things well, 1 point is given and when he belongs very much to that group, 0 points are given. A higher score indicates a worse reported memory.

In the *Everyday Memory Questionnaire for children, parent version* (EMQ-parent; Van Leeuwen, 1993) 24 items question the parents about their child's memory. Questions ask, for example if the child is perceived being able to remember a song or a telephone number. Each question is rewarded by a score from 0 to 4. The higher the score, the more memory problems are reported.

Working memory tests

Digit Recall and Nonword Recall (Baddeley, 1986) both measure verbal short-term memory (STM), an aspect of WM. In these tests digits, respectively nonwords, have to be repeated in the same order as they were presented. Both tests start with sequences of two items (digits or nonwords) up to six. In both tests three trials are available for each sequence, but when two trials were repeated correctly, the third was omitted but awarded by one point. To assess visual STM, two tests were administered. *Block Recall* is identical to the Corsi test, but in this study we used the instructions from Pickering and Gathercole (2001). The experimenter taps a sequence of three-dimensional blocks that the child has to repeat in the same order. The task starts with one block up to sequences of nine blocks. For every sequence, six trials are available. In the *Visual Patterns test* (Della Sala, Gray, Baddeley, & Wilson, 1997) the child is shown a matrix depicted on a stimulus card, varying in configuration from 2×2 to 5×6 squares in which half of the squares are marked. After inspecting a stimulus card for 3 seconds, the child has to indicate the marked squares in the blank grid on the response sheet. Three stimulus cards are available for each of the fourteen difficulty levels.

Two verbal WM tests were administered. In *Backward Digit Recall* (Pickering & Gathercole, 2001) the child has to repeat spoken lists of digits, but in the reverse order. Procedure and scoring for this task is similar to Digit Recall. *Listening Recall* (Pickering & Gathercole, 2001) requires the child to listen to simple statements and to determine whether they are true or false, while at the same time remembering the last word of each statement. Following each trial, these last words have to be repeated in the same order as presented. Listening Recall starts with one sentence, up to a maximum of six. Six trials are available for each sequence and the next sequence is presented upon four correct trials, rewarding the omitted trials with one point each. The *Odd-One-Out test* (Henry, 2001) measures visual WM. Because Henry reported a possible ceiling effect we extended the test with an extra item in consultation with her (L. A. Henry, personal communication, April 27, 2005). Each trial contains a sequence of three indefinable figures of which two are similar and one is slightly different: the odd-one-out. The child has to decide which one is the odd-one-out and remember its location. Following each trial, the child has to point to the locations of the odd-one-outs in the same sequence as presented. Trials start with two sequences, up to a maximum of six. Three trials are available for each sequence length.

Data analysis

First, scores from the RBMT, the EMQ-child and the STM and WM tests were submitted to a multivariate analysis of variance (MANOVA). Because data for $n = 17$ children were missing on the EMQ-parent, it was analyzed separately by a univariate analysis of variance (ANOVA). The Scheffé procedure was used for post-hoc analyses in case variances of the tests were comparable, and Tamhane's procedure in case variances differed. The next step was to look at correlations between the RBMT and questionnaires versus the WM scores, using bivariate correlation analysis. Finally, stepwise linear regression analyses were carried out for each of the three groups to investigate which STM and WM tests mostly determine the score on EM indexed by the RBMT Screening score and the three selected subscores.

Results

Table 2 shows mean scores, standard deviations, group effects and effect sizes of all administered tests and questionnaires.

Everyday memory performance

MANOVA revealed significant group effects for all RBMT scores except RBMT Visual recognition. Post-hoc analyses showed that the MID group performed less well than the CA control group on RBMT Screening ($p < .01$), RBMT Story ($p < .01$),

Table 2 Performance of the groups on the memory tasks

	MID ($n = 39$)		CA-CON ($n = 39$)		MA-CON ($n = 26$)			
	M	SD	M	SD	M	SD	F (p)	d CA/MA
EM								
RBMT Screening (12)	8.51	1.94	10.95	.94	9.77	1.45	25.38 (.00)	1.60/.36
RBMT Story (42)	9.32	5.01	16.74	5.16	10.77	4.84	23.23 (.00)	1.30/.29
RBMT Visual recognition (15)	14.90	.38	14.95	.22	14.85	.54	.57 (.57)	.16/.10
RBMT Route recall (10)	8.87	1.52	9.95	.22	9.92	.27	15.21 (.00)	.99/.96
EMQ-child (27)	10.97	4.70	10.33	7.35	7.77	3.38	2.74 (.07)	.10/.78
	($n = 33$)		($n = 28$)		($n = 26$)			
EMQ-parent (96)	32.30	16.11	15.71	11.11	18.85	11.84	13.29 (.00)	1.19/.95
	($n = 39$)		($n = 39$)		($n = 26$)			
STM and WM								
Digit Recall (18)	10.49	2.34	14.26	2.20	10.92	1.96	32.97 (.00)	1.66/.20
Nonword Recall (18)	5.13	1.98	7.21	2.00	6.46	1.79	11.37 (.00)	1.04/.70
Block Recall (54)	25.41	3.10	30.31	4.31	27.42	2.48	19.42 (.00)	1.30/.72
Visual Patterns (42)	15.28	3.30	20.26	3.88	14.69	3.87	24.76 (.00)	1.38/.08
Backward Digit Recall (18)	5.74	1.97	8.62	2.67	6.88	1.99	25.93 (.00)	1.23/.28
Listening Recall (36)	12.41	3.59	16.23	2.92	14.50	2.40	15.02 (.00)	1.17/.68
Odd-One-Out (15)	7.74	3.08	11.26	2.64	8.42	4.03	12.89 (.00)	1.23/.19

(Cohen´s) *d*, effect size (.1 – .3 small, .3 – .5 moderate, .5 – 1.0 large, > 1.0 very large). Numbers before the slash represent the effect with regard to the CA group, behind the slash with regard to the MA group.

and RBMT Route recall ($p < .01$), while both groups scored comparable on RBMT Visual recognition. Compared to the MA group, children in the MID group scored significantly lower on RBMT Screening ($p < .01$) and on RBMT Route recall ($p < .01$). However, as the score of RBMT Route recall contributes to the score on RBMT Screening, the analysis was repeated with RBMT Route recall as co-variate. The results confirmed a significant lower score on RBMT Screening for the MID group compared to both the CA and the MA control group ($p < .01$).

Contrary to the EMQ-child, where no significant group effect was found, a significant group effect (ANOVA) was found for the EMQ-parent. Post-hoc analyses revealed that parents of the children with MID perceived their child's EM worse, indicated by a higher score, than did both the parents of the CA children ($p < .01$) and the parents of the MA children ($p < .01$).

Short-term memory and working memory performance

MANOVA revealed furthermore significant group effects on Digit Recall and Nonword Recall. Post-hoc analysis indicated that for Digit Recall, the MID and MA groups performed equally, but both groups did worse than the CA group (*ps* $< .00$). The post-hoc analysis for Nonword Recall showed that the MID group performed less well than the MA and CA groups ($p < .05$ and $p < .00$, respectively).

For both Block Recall and the Visual Patterns tests, MANOVA revealed significant group effects. Post-hoc analysis indicated that on Block Recall the MID group performed worse than the MA group ($p < .05$) and the CA group ($p < .00$). On the Visual patterns test, however, the MID group performed equally well as the MA group, but less well than the CA group ($p < .001$).

MANOVA revealed that the MID group performed worse on Listening Recall than the MA group on ($p < .05$) and the CA group ($p < .001$). On Backward Digit Recall the MID and MA group did not differ. However, the MID group performed worse than the CA group ($p < .001$). To be sure that the differences on both verbal WM tasks were not caused by a verbal STM delay, a MANCOVA was performed with Nonword Recall as covariate. The analysis showed that despite this correction the effects remained. Analysis of the Odd-One-Out test scores showed significant group effects. The MID group performed similar to the MA group, but less well on this test than the CA group ($p < .01$). When correcting for Block Recall (MANCOVA), the effect remained.

In sum, the MID group performed worse on most EM tests than the CA control group, but on RBMT Visual recognition both groups performed similar. In regard to the MA control group, the children with MID did as well on RBMT Story recall and on RBMT Visual recognition. However, on RBMT Screening score and on RBMT Route recall the children with MID performed less well than the MA control group. The three groups of children rated their own memory functioning comparable. However, the parents of the children with MID rated their child's memory as worse than did the parents of both control groups. On all WM tests, the children with MID did less well than the CA control children. On four of these tests the children with MID did as well as the MA control children, but they did worse on Nonword Recall, Block Recall, and Listening Recall.

Associations between everyday memory and working memory performance

Table 3 shows only the statistically significant correlation coefficients between tests for each of the groups. For the MID group, we found significant correlations between RBMT Screening score and Digit Recall and between RBMT Route recall and Block Recall. For the CA group we found a significant correlation between the EMQ-child and the EMQ-parent, and between the EMQ-child and Block Recall. The MA group showed significant correlations between RBMT Screening score and Nonword Recall, between RBMT Story recall and Listening Recall and between RBMT Route recall and Nonword recall and finally a near significance correlation between RBMT Screening score and Listening Recall.

A series of stepwise multiple regression analyses were conducted for each group, using

Table 3 Correlation coefficients (p values) for the memory tasks

Tests	MID $r(p)$	CA $r(p)$	MA $r(p)$
RBMT Screening – Digit Recall	**.35** (< .05)	–.19 (= .91)	–.06 (= .76)
RBMT Screening – Nonword Recall	.25 (= .13)	.05 (= .88)	**.39** (< .05)
RBMT Screening – Listening Recall	–.06 (= .69)	.14 (= .40)	.37 (= .06)
RBMT Story recall – Listening Recall	.13 (= .42)	.14 (= .40)	**.39** (< .05)
RBMT Route recall – Block Recall (STM)	**.43** (< .01)	–.04 (= .82)	–.13 (= .53)
RBMT Route recall – Nonword Recall (STM)	.07 (= .65)	–.27 (= .10)	**.49** (= .01)
Parent Questionnaire – Youth Questionnaire	.19 (= .28)	**.52** (< .01)	–.11 (= .60)
Youth Questionnaire – Block Recall (STM)	.13 (= .36)	**–.34** (< .05)	.01 (= .97)

the RBMT Screening score as dependent outcome variable and all WM and STM scores as independent variables. In the MID group, Digit Recall accounted for 12% of the variance in RBMT Screening score, $\beta = .35$; $F(1,37) = 5.12$, $p < .05$. In the CA group, the RBMT total score was not explained by any of the WM and STM scores. For the MA group, it was Nonword Recall accounting for 16% of the variance of the RBMT Screening score, $\beta = .40$, $F(1,24) = 4.46$, $p < .05$.

The other RBMT outcome measures (RBMT Story, Visual recognition and Route recall) and both the EMQ-child and EMQ-parent were analyzed in the same way as the RBMT Screening score (stepwise with all STM and WM scores as independent variables). This was done explorative as we acknowledge that performing many analyses might lead to spurious findings. For the children with MID, Block Recall accounted for 18% of the variance in RBMT Route recall, $\beta = .43$; $F(1,37) = 8.34$, $p < .01$. Variance of the other outcome variables was not explained by any of the STM and WM test scores. In the CA group only the score on the EMQ-child was explained by one of the independent variables, Block Recall, which explained 11%, $\beta = -.34$; $F(1,37) = 4.93$, $p < .05$. For the MA children, Nonword Recall explained 24% of the variance of RBMT Route recall, $\beta = .49$; $F(1,24) = 7.42$, $p < .05$, and Block Recall explained 16% of the variance of RBMT Pictures, $F(1,24) = 4.72$, $p < .05$.

In sum, associations (by correlations and regression analyses) are found between RBMT scores and STM and WM scores for both MID and MA control children, while these were not found for CA control children.

Discussion

Results of the present study show that children with mild intellectual disabilities (MID) perform less well than CA control children on three aspects of memory in everyday life as measured with the RBMT: total Screening score, Story recall and Route recall. However, on Visual recognition both groups scored comparable. This visual recognition strength is in line with the results of the study of Martin et al. (2000). In comparison with MA control children, the children with MID performed equally well on recalling a story and on recognizing pictures. In contrast, the children with MID had a lower score on the total Screening score and on Route recall than the MA control children.

The fact that we did not find a delay in recalling a story contrasts with the results of Martin et al. (2000). This might be due because of the within-group analyses Martin et al. (2000) performed. Their population had more difficulties with Story recall than with other tests, but their performances were not compared with control groups.

The total Screening score is lower for children with MID than for the MA control children, even when corrected for Route recall. This is probably caused by the relatively strictness of assigning screening points: only when all aspects of a subtest are correctly remembered, one screening point is given. The relatively weak performance on Route recall might be explained by the fact that it is a quite complex task. The child has not only to remember the places to walk to, but also to remember to pick up an envelope and in the end to put it down on a specific place. Therefore, a good working memory (WM) seems to be crucial for this everyday memory (EM) task, while this is precisely a weak point in children with MID (e.g. Van der Molen et al., submitted).

The delay in EM for children with MID was confirmed by their parents as they rated their child's memory as less good than did the parents of both the MA and CA control children. Interestingly, the children with MID themselves stated otherwise; they rated their own memory being as good as the MA and CA control children. This finding is consistent with the results reported by Elias (2005). She compared perceived cognitive competence of children with MID (aged 6 – 8 years) with the judgment of their own teacher and did the same for typically developing children (aged 6 – 8 years). Children with MID were less capable of judging their cognitive competence accurately, they overestimated their competencies compared to typically developing children. Crabtree and Rutland (2001) obtained similar results for children with intellectual disabilities (mean age 14 years) who had to rate, among other things, their own scholastic functioning. There were no differences in their scholastic evaluation compared to typically developing children, even when the children with intellectual disabilities were explicitly asked to compare themselves with typically developing children. It seems that the children with intellectual disabilities deliberately (consciously or unconsciously) evaluate themselves as able as the control children so as to protect their cognitive self-worth. A study by Gilger (1992) also showed that the younger and the less intellectual capable, the less one is able to evaluate one´s own competencies.

Furthermore, the children with MID did less well than the CA control group on all verbal and visual STM and WM tests. Compared to the MA control children, the results showed a fractionated pattern as the children with MID performed worse on Nonword Recall (verbal STM), Block Recall (visual STM) and Listening Recall (verbal WM), while they performed comparable on the other four tasks. Specific STM and WM strengths and weaknesses, instead of an overall delay, have been reported before in populations with intellectual disabilities (e.g. Henry & MacLean, 2002; Rosenquist, Conners, & Roskos-Ewoldsen, 2003; Van der Molen et al., 2007).

The relationship between EM and WM was analyzed separately for each of the three groups; children with MID, CA and MA control children. For both the children with MID and the MA control children, but not for the CA control children, we found low to moderate ($r = .34 - r = .52$) correlations between RBMT indices and WM and STM test scores. Among children with MID, associations were found between the total EM index (RBMT Screening) and verbal STM (Digit Recall), and on remembering a route (RBMT Route recall) and visuo-spatial STM (Block Recall). These results correspond with the findings from Numminen et al. (2000) who reported associations between EM and STM and WM measures in *adults* with intellectual disabilities. For the MA control group, associations were found between the total EM index (RBMT Screening) and verbal STM (Nonword Recall), between remembering a story (RBMT Story recall) and verbal WM (Listening Recall) and between remembering a route (RBMT Route recall) and verbal STM (Nonword Recall).

A difference that should be noted refers to the fact that for children with MID a relationship existed between scores on RBMT Route recall and visuo-spatial STM performance (Block Recall), while for the MA control children scores on RBMT Route recall were associated with verbal STM performance (Nonword Recall). Although these outcomes should be interpreted cautiously because of the many correlations performed, this finding was confirmed by regression analyses which showed that scores on Block Recall accounted for 18% of the variance in scores on Route recall in children with MID, while for the MA control children it was scores on the Nonword Recall test which explained 24% of the variance in scores on Route recall. This difference might be due to the way the children process visuo-spatial information. Several studies showed that younger children rely more on visual codes, but at around 8 years of age they recode visual information into verbal information, making it easier to rehearse. (e.g. Hitch, Halliday, Schaafstal, & Schraagen, 1988 cited in Alloway, Gathercole, & Pickering, 2006; Pickering, 2001). Indeed, children who label visual information verbally, remember more visual information than children who do not use verbal labeling (Pickering, 2001). It seems that in this study, the MA control children indeed used the strategy of recoding the visual information, while the children with MID did not. This might also be the reason why the children with MID performed worse on Block Recall than the MA children. Furthermore, a study by Fenner, Heathcote, and Jerrams-Smith (2000) showed that children who score low on tasks of visual-spatial ability, exhibit more problems with way finding than children who score high on visual-spatial tasks. A result which is confirmed by our own study.

Although we did find associations between the RBMT indices and scores on the STM and WM tests, we did not find these for the CA control children. It is possible that the EM demands thought to be assessed by the RBMT are not complex enough for these children to force them to use their STM or WM all too strongly (and hence prevent to reveal the possible association with the EM outcomes). Indeed, the RBMT was originally developed to detect memory defects from the age of 16 years on, although it can be successfully used with younger children (Wilson et al., 1985). Therefore, one might expect the highest scores for the CA control children, as the demands for them are considerably more routine like. In addition, both the MID group and MA group are expected to show more variance in scoring because for them, the RBMT tasks are more demanding. Furthermore, people are said to use their WM when activities are less routine like (Unsworth & Engle, 2007), hence this might explain why the CA control children do not show associations between the RBMT indices and WM tasks.

In conclusion, that pattern of findings that emerged from the current study suggest that EM is delayed in children with MID. This means that the memory demands in everyday life are more challenging for children with MID than they are for typically developing children. Although several studies have focused on EM training in aging people (with mild cognitive impairment or Alzheimer´s disease) which on average showed moderate effects (see for a review Sitzer, Twamley, & Jeste, 2006), no such study has been carried out in respect to children with intellectual disabilities. It would be interesting to see if EM training has effect in children with MID. It might be more effective however, to provide children with MID with a more basic cognitive training, such as a WM training, as WM seems particular weak in these children and WM is considered to be important for the successful implementation of complex cognitive activities in everyday situations (Gathercole & Alloway, 2006). Studies on WM training have been carried out successfully in, for example, children with ADHD, knowing to have a relatively weak WM as well (e.g. Klingberg, Forssberg, & Westerberg, 2002). Future research should reveal whether memory training can be effective in improving EM functioning in children with MID.

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5

Effectiveness of a computerized working memory training in children with mild intellectual disabilities

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Abstract

The goal of this study is to evaluate the effectiveness of a computerized working memory (WM) training on memory, response inhibition, fluid intelligence, scholastic abilities and the recall of stories in children with mild intellectual disabilities (MID). A total of 95 children with MID (age range 13–16 years) were randomly assigned to either training group A ($n = 41$), receiving a training adaptive to each child's progress in WM, training group B ($n = 27$), receiving the same but less demanding WM training, or to a Control group ($n = 27$) receiving training without WM demands. The three groups completed the computerized training program for five consecutive weeks, three times a week for six minutes. Primary outcome measures included performance on short-term memory and WM tasks. Secondary outcome measures included performance on response inhibition, fluid intelligence, scholastic abilities and story recall tasks. A significant positive training effect was found on verbal short-term memory for training group A and on visual WM for group B. In addition, both training groups showed better performance at follow-up, relative to the Control group, on scholastic abilities and story recall. The results indicate that WM training can be effective in children with MID and, thus, open promising vistas for developing strategies aimed at increasing mnemonic abilities in this vulnerable group.

Introduction

Working memory (WM), the ability to maintain and process information simultaneously during the performance of a cognitive task, is central to fluid intelligence (e.g., Ackerman, Beier, & Boyle, 2005) and executive function like response inhibition (e.g., Garon, Bryson, & Smith, 2008), and is of great importance for the development of children's scholastic abilities like arithmetic and reading (e.g., Hitch, Towse, & Hutton, 2001). It has been suggested that even a small increase in the efficacy of WM will lead to significant improvements in classroom and daily life functioning in children (Minear & Shah, 2006). WM training studies have been shown effective in various populations including the elderly (Craik et al., 2007), people with schizophrenia (Kurtz, Seltzer, Shagan, Thime, & Wexler, 2007), children with attention-deficit/hyperactivity disorder (Klingberg et al., 2005) and children with acquired brain injuries (Van 't Hooft et al., 2007).

The current study focuses on children and adolescents with mild intellectual disabilities (MID; IQ score 55 – 85). This youth is known to have WM problems (Henry, 2001; Maehler & Schuchardt, 2007; Van der Molen, Van Luit, Jongmans, & Van der Molen, 2007; Van der Molen, Van Luit, Jongmans, & Van der Molen, submitted) and generally requires more educational support than do typically developing pupils (Simonoff et al., 2006). Given the relationship between WM performance on the one side and scholastic abilities, response inhibition and fluid intelligence on the other side it is, therefore, of interest to study the feasibility and effectiveness of a WM training in children with MID on those aspects.

WM is considered to depend simultaneously on (verbal or visuo-spatial) short-term memory (STM) and the control and regulation of attention (or the so-called 'central executive' system; Baddeley, 1986; Cowan, 1999; Engle, Kane, & Tuholski, 1999). Information held in verbal STM can be rehearsed automatically by people aged 7 and over (Baddeley, 1986; Gathercole, Adams, & Hitch, 1994) to prevent the information from fading away. Studies investigating the effects of memory training programs in people with intellectual disabilities focussed primarily on verbal STM; more specifically on the rehearsal aspect of STM (e.g., Comblain, 1994; Conners, Rosenquist, Arnett, Moore, & Hume, 2008; Conners, Rosenquist, & Taylor, 2001; Engle & Nagle, 1979; Kellas, Ashcraft, & Johnson, 1973; Laws, MacDonald, & Buckley, 1996). Generally, these training programs are successful, in that the trained people with intellectual disabilities improve in their ability to repeat items in the correct order. However, use of the rehearsing strategy beyond the training domain, as far as assessed, is problematic (Bebko & Luhaorg, 1998). Moreover, follow-up studies showed that the effect of this specific training deteriorates with time (Laws, MacDonald, Buckley, & Broadley, 1995).

It is striking that, while attempts have been made at training verbal STM, WM training has not been reported previously in people with intellectual disabilities (Minear & Shah, 2006). This omission is unfortunate because, as discussed above, WM is especially weak in children and adolescents with MID and it is WM above all that is associated with scholastic abilities. Moreover, in children with ADHD, a computerized WM training has shown positive results (Klingberg et al., 2005, see also Klingberg, Forssberg, & Westerberg, 2002, for a study in small groups of children with ADHD and university students). That study showed that it is possible to improve visual and verbal WM, response inhibition and fluid intelligence by a training consisting of visuo-spatial WM and verbal STM tasks adjusting to each child's level of progression (Klingberg et al., 2005). The effects were shown immediately after training and at follow-up, although at follow-up the effect on fluid intelligence disappeared.

In the current study we developed a different computerized WM training, coined 'Odd Yellow', based on our reading of the pertinent literature and on recommendations of an expert panel of professionals with extensive experience in working with children with MID. Three versions of the 'Odd Yellow' WM training were constructed: Training A adjusts to the child's progress in performance during the training sessions, Training B is at a lower and fixed level of demand. This low level training was included to assess whether stimulating WM alone, without challenging it, would be sufficient to be effective. Finally, the Control training was nearly identical to Training A without placing any demand on the child's mnemonic ability. The duration of each training session, 6 minutes, was well within the attention span of most children with MID as observed in our pilot study. In addition, the computer screen included a time counter for encouraging the child to complete the session and the child was told that the completion of the training would be rewarded by a personal certificate. Finally, the computerized training allowed for evaluating training compliance and data transmission using shielded internet connections.

To evaluate the effect of the training, an extensive test battery was administered immediately before and after the training, as well as 10 weeks after the training. The test battery included primary outcome measures for STM and WM and secondary outcome measures for scholastic abilities (i.e., arithmetic and reading) and story recall, both included based on a recommendation by Klingberg et al. (2005; see also Minear & Shah, 2006), and furthermore for response inhibition and fluid intelligence.

We expected both group A and group B to perform better on primary and secondary outcome measures compared to the Control group, immediately after training and, hopefully at follow-up. Exploratively, we looked at differences in effects between group A and group B. To compare the attractiveness of training A and B and of the Control training, we asked all children immediately after the training to indicate how much they liked the training and how much effort they put in to it.

Methods

Participants

Of the 13 schools for pupils with MID who were asked to participate in this study, 1 school refused without reason and 5 were interested but too busy to co-operate at that moment. The remaining 7 schools were willing to participate in the study. The schools were located in three different provinces in The Netherlands. Within the age range of 13 till 16 years, 95 children were selected to participate in the training. Contra-indicated for selection were children classified by psychiatrists based on the DSM-IV-TR (American Psychiatric Association, 2000) as having Attention Deficit/ Hyperactive Disorder (ADHD) or an Autism Spectrum Disorder (ASD), as these psychiatric problems are known to be associated with specific WM strengths and weaknesses (Minear & Shah, 2006) and children who were previously hospitalized because of serious (head) injuries. From two children there were no scores on the post tests (because of illness) and for six other children there were no scores of the follow-up tests (all because of illness). See Figure 1 for the participants' flow.

Children were randomly assigned to either training A (group A), training B (group B) or to the Control training (control group). Group A consisted of 41 children (23 boys, 18 girls) with a mean age of 15.3 years (SD = .68) and, as an index of fluid intelligence,

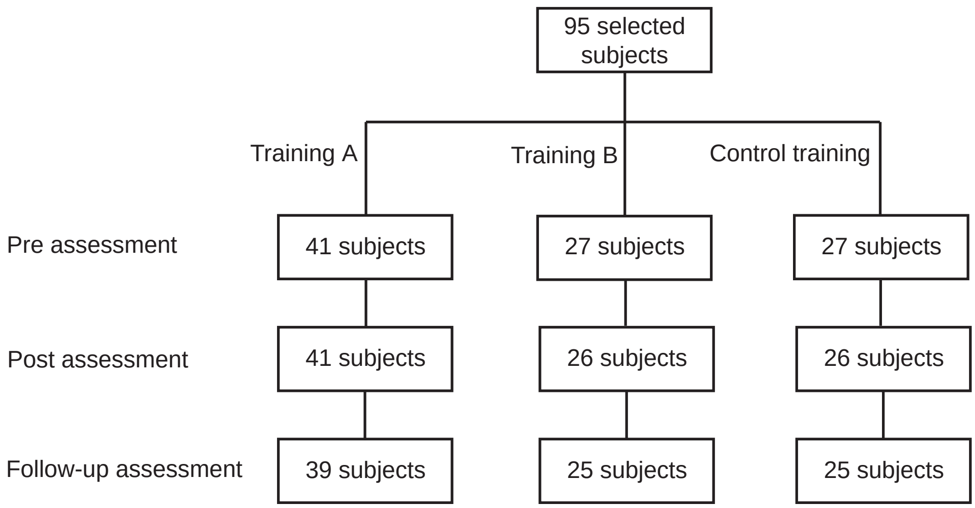


Figure 1 Flow of participants through the trial.

a mean Raven score of 35.4 (SD = 6.26), group B contained 27 children (15 boys, 12 girls) with a mean age of 15.0 years (SD = .70) and a mean Raven score of 32.7 (SD = 7.91) and the Control group also included 27 children (16 boys, 11 girls), with a mean age of 15.4 years (SD = .66), and a mean Raven score of 33.4 (SD = 5.29). The three groups did not differ in age, $F = 2.2$, $p = .12$, nor in fluid intelligence (Raven SPM), $F = 1.4$, $p = .24$.

Study design

A randomized, single-blind controlled trial was conducted between February and June 2007. Schools were approached and informed about the study and the inclusion and exclusion criteria. Based on these criteria, teachers referred suitable children. After obtaining informed consent, all children were tested five times. They were tested twice using the same test battery within a 4-week period (pre-test 1 and pre-test 2). This was followed by a 5-weeks training program. Following the training, the children were tested twice again within a 4-week period (post-test 1 and post-test 2). Finally, ten weeks after the training, the test battery was administered for the last time (follow-up test). Thus all tests were administered five times except the Raven SPM, which was administered three times (during the pre-, post- and follow-up period).

Within schools, the assignment of each child to one of the three conditions (i.e., training A, training B, or the Control training) was at random. Thus, at each of the seven schools all three conditions were available. The children and teachers were blind to the fact that there were three separate training versions. Teachers prompted the children to perform the training sessions at the specified times (three times a week). The computers used for training (both PC's and Mac's were used) were connected to internet for checking training compliance and progress. After follow-up testing, all children received a small present and a certificate testifying they had completed a memory training.

Primary outcome measures

STM and WM

Two verbal and two visual STM tests were used. *Digit Recall* and *Nonword Recall* (Pickering & Gathercole, 2001) both measure verbal STM. Both tests require repeating digits or nonwords in the same order as presented. Digit Recall starts with two digits up to eight, while Nonword Recall starts with one nonword up to six. Six trials are available for each sequence. Scores vary from 0 to 48 (digits) or from 0 to 36 (nonwords).

Visual STM was assessed by using *Block Recall* and the *Visual Patterns test*. Block Recall is identical to the Corsi test (see Lezak, 1995), but in this study we used the instructions from Pickering and Gathercole (2001). The experimenter taps a sequence of three-dimensional blocks that the child has to repeat in the same order. The task starts with one block up to sequences of nine blocks. For every sequence, six trials are available. Scores vary from 0 to 54. In the Visual Patterns test (Della Sala, Gray, Baddeley, & Wilson, 1997) the child is shown a matrix depicted on a stimulus card, varying from 2x2 to 5x6 squares with half of the squares being marked. After inspecting a stimulus card for three seconds, the child has to indicate the marked squares using a blank grid on the response sheet. Three stimulus cards are available for each of the fourteen difficulty levels. Scores vary from 0 to 42.

Two verbal and one visual WM tests were used. The two verbal WM tests were *Backward Digit Recall* and *Listening Recall*. Backward Digit Recall (Pickering & Gathercole, 2001) requires repeating spoken lists of digits, but in the reverse order. Listening Recall (Pickering & Gathercole, 2001) requires listening to simple statements to determine whether they are true or false, while at the same time remembering the last word of each statement. Following each trial, these last words are to be repeated in the same order as presented. Trials in Backward Digit Recall start with two digits up to seven, while Listening Recall starts with one sentence, up to a maximum of six. For both tests, six trials are available for each sequence and scores vary from 0 to 36.

Visual WM was examined using a manual version of the *Spatial Span* (Alloway, 2007). A card is shown with two shapes of which the right one has a red dot on top. The right shape can be exactly the same (p–p) or opposite (p–q) to the left shape and it can be rotated in three different ways (0°, 240° and 360°). The child has to decide whether the shape at the right is the same or opposite to the left shape. At the same time, the position of the red dot on the right shape has to be remembered, which can be at three different locations according to the three rotation possibilities. After each trial, the child has to point to one of three dots (at 0°, 240° or 360°) to indicate which dots were on the stimuli cards and in which sequence. Trials start with one card up to a sequence of six. Scores can vary from 0 to 42.

Secondary outcome measures

Scholastic abilities

Two tests were administered to tap scholastic abilities, one test for arithmetic and another one for reading abilities. In the *Arithmetic test* (De Vos, 1992) the child is presented five rows for different arithmetic operations: adding, subtracting, multiplying, dividing and a row combining the four operations. The child has to complete as many items in each row as possible within one minute by writing down the correct answer. For every correct answer, one point is given. Total score is the total amount of correct scores for all five rows with a minimum of 0 and a maximum of 200. In the *Reading test* (Brus & Voeten, 1973), the child is presented with a list with 116 unrelated words of increasing difficulty and has to read aloud as many as possible within one minute. Total score is the amount of correct read words varying from 0 to a maximum of 116.

Story Recall

In *Story Recall*, the experimenter reads out loud a short story after which the child immediately has to repeat it as exactly as possible (immediate recall). After twenty minutes the child is asked to repeat the story a second time (delayed recall). Total score, indexed as correct key words of the story in both immediate and recall condition, varies from 0 to 29.

Response inhibition

The *Stroop* (Hammes, 1978), measuring response inhibition, consists of three cards. First, the child has to read as quickly as possible the names of four colors (yellow, red, green and blue) written on the first card. Then on the second card, the child sees blocks filled in with the four colors and has to name these as quickly as possible. Finally on the third card, the words of the four colors are written and printed in a different color. The child has to name the color in which the words are printed and inhibit the prepotent response to name the word. The total (inference) score is the amount of seconds needed to read out the third card minus the seconds needed for the second card. Scores can vary as they depend on how long the child takes to read aloud card two and card three. The less interference time, the better the achievement.

Fluid intelligence

Finally, the *Raven Standard Progressive Matrices* (Raven, Court, & Raven, 1996) was administered to assess fluid intelligence. The child is presented with pieces of wallpaper on which one part is missing. The child has to choose the correct missing part out of different alternatives. Other tasks within this test consist of rows of symbols with a missing one: the child has to decide which of the alternative symbols given, logically completes the row. The test starts relatively easy but increases in difficulty. One point is given for each correct answer. Minimum score is 0 and maximum score is 60.

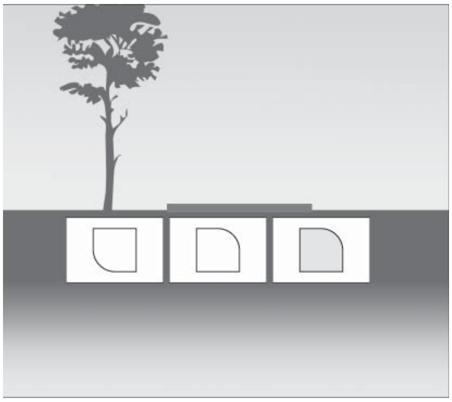
Motivation

To assess whether training A, B and the Control training were equally appealing to the children, we asked the children after the training to rate how much they liked the training using a scale from 0 (I did not like it at all) till 10 (I did enjoy it very much). They were also asked to rate their effort invested in the training using a scale from 0 (I did not my best at all) till 10 (I did very much my best).

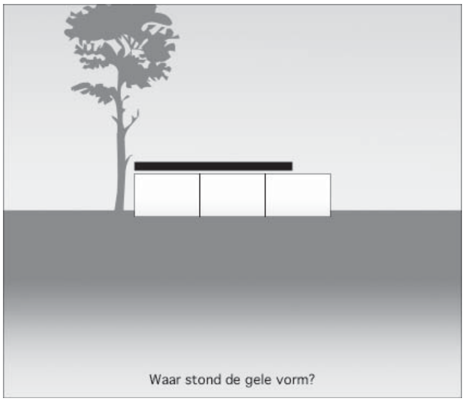
Training program

Training A

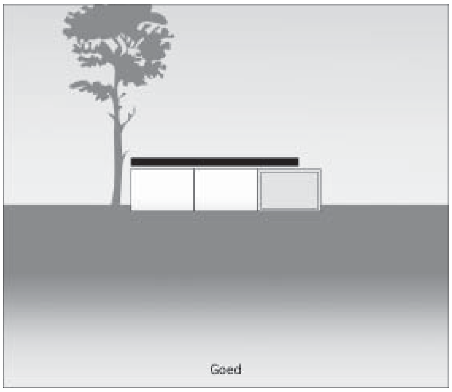
We developed a computerized 'Odd Yellow' training based on the principle of the Odd-One-Out test by Henry (2001). Three times a week, during a 5-week period, the child is trained for 6 minutes. After logging in, the session starts with a brief explanation. Then the child is shown three figures (for an example see Figure 2), of which two are identical in shape and one is slightly different in shape, the odd-one-out. Also, of the three figures, two are drawn in white and black and one in yellow and black. First, the child has to tap the odd-one-out as quickly as possible by use of the mouse prompted by a visual timer, a line which decreases in length and disappears within five seconds (see Figure 2). After clicking the odd-one-out, or following 5 seconds when the child omitted to respond (receiving the feedback 'too late'), 2 seconds are provided to remember the position of the yellow figure. These 2 seconds are represented by a visual timer as well. When the 2 seconds are expired, an empty matrix is shown representing the positions of the three figures. The child, again forced by a 5-second visual timer, has to tap the position of the yellow figure. Trials start with one sequence of three



(a)



(b) What was the location of the yellow figure?



(c) Correct

Figure 2
Stills from the WM training. Three figures are shown. The figure which is slightly different in shape, in this case the left one, has to be clicked on with the mouse. The grey line on top of the symbols, i.e. the time bar, fades to the left so as to force the child to choose the odd-one-out within five seconds (a). Then the child gets 2 seconds to remember the place of the yellow figure, after which the child is asked to click the empty box where the yellow figure went (b). The child clicked in the right box (c).

figures and can increase to seven sequences of three figures each. When two trials of the same sequence are failed, that is when the positions of the yellow figures are not remembered correctly, trials with one sequence less are presented.

Training B

This training is similar to training A except that trials do not exceed more than two sequences. The child is presented trials of one or of two sequences in random order.

Control training

The format for the Control training is similar to training A except that now only the odd-one-out has to be detected as soon as possible while the position of the yellow figure can be ignored.

Data analysis

First, the motivation rates were compared between the three groups by use of MANOVA. Then test-retest reliabilities of all administered tests were calculated by means of Pearson correlation coefficients for pretest condition (*r* pretest 1 – pretest 2) and posttest conditions (*r* posttest 1 – posttest 2). Then data from both pre-test sessions (pre-test 1 and pre-test 2) and post-test sessions (post-test 1 and post-test 2) were averaged resulting in three scores per child: mean pretest score, mean posttest score and one follow-up test score.

As the interest of the training effects centered on constructs rather than single test scores, the analyses were done on combined test scores indexing the same underlying construct. Because the tests had different scales, individual test scores all were first linearly transformed to a scale with a minimum score of 0 and a maximum score of 10. An exception was made for the Stroop test as it has no maximum score, so the original score in seconds was retained. This resulted in eight variables: Verbal STM (compound score for Digit Recall and Nonword Recall), visual STM (Block Recall and Visual Patterns test), verbal WM (Listening Recall and Backward Digit Recall), visual WM (Spatial Span), scholastic abilities (arithmetic test and reading test), Story Recall (immediate and delayed), response inhibition (Stroop) and fluid intelligence. Unlike the other measures, a lower score on the Stroop indicates a better performance. We contrasted the performances of both group A and group B with the Control group. As we expected both groups A and B to perform better than the Control group after the training, planned comparisons were used (i.e. one-sided). Similar to Klingberg et al. (2005) a general linear model analysis (GLM) was performed controlling for baseline scores (pre-testing). To assess whether the observed effects were stable, the outcome measures at follow-up were examined using a GLM, controlling for post-testing score. When significant effects were found for a compound variable, the individual test scores, contributing to this particular compound score were analysed, so as to see if both or one of the test scores contributed to the effect.

Results

First of all, the three groups did not differ either on the ratings of how much they liked the training, with mean scores varying between 7.2 and 7.5, and in the scores they reported regarding the effort they invested in the training, with mean scores varying from 7.8 to 8.1 ($F(2,91) = .35$, $p = .85$).

As can be seen in Table 1, test-retest correlation coefficients in the pre-testing condition varied from moderate (r = .55, Listening Recall) to excellent (r = .96 for both the Arithmetic test and the Reading test). At post-testing, reliability was higher for Listening Recall (r = .65) but the reliability of Spatial Span dropped from r = .67 in the pre-testing condition to r = .46 in the post-testing condition.

Mean raw scores (SD) of the three groups on all tests are shown in Table 2a and Table 2b. The outcome of the GLM's revealed that group A obtained a significant higher score on the verbal STM compound score in the post-training condition than at pre-training condition compared to the Control group. See Table 3 for η_p^2, *B* and one-sided *p* for all compound scores and for mean values corrected for baseline measurement.

Furthermore, the progress in scores from pre- (time 1) to post- (time 2) to follow-up testing (time 3) for each of the three groups is shown in Figure 3. Analyses of the individual test scores showed that the mean Digit Recall score at this point in time was higher for group A than for the Control group (η_p^2 = .04, *B* = .94, *p* = .03), while this was not the case for scores on Nonword Recall. The effect on Digit Recall remained at follow-up.

No other significant results were found from pre- till post-testing, but from post- to follow-up assessment significant differences appeared on several compound scores for both group A and group B compared to the Control group. Compound Visual STM scores increased for group A and for group B compared to the Control group. Analyses on the individual visual STM test scores indicated that for both groups the increase was explained by a higher score on Block Recall (group A, η_p^2 = .09, *B* = 2.07, *p* = .003; group B, η_p^2 = .10, *B* = 2.2, *p* = .001). Visual WM, indexed by the task Spatial Span, also increased

Table 1 Test-retest reliability for all tests (Pearson correlation coefficients)

	DR	NR	BlR	VP	BR	LR	SpS	Ar	Re	SRi	SRd	ST	R
Raw scores (*n* = 96) pre1 – pre2	.76	.73	.67	.59	.57	.55	.67	.96	.96	.60	.65	.62	.64
Raw scores (*n* = 87) post1 – post2	.86	.76	.62	.69	.68	.65	.46	.97	.97	.76	.89	.60	.70

DR, Digit Recall; NR, Nonword Recall; BlR, Block Recall; VP, Visual Patterns Test; BR, Backward Digit Recall; LR, Listening Recall; SpS, Spatial Span; Ar, Arithmetic; Re, Reading; Sri, Story Recall immediate; SRd, Story Recall delayed; ST, Stroop test; R, Raven SPM.

Table 2a Mean scores (Standard Deviations) for primary outcome measures of STM and WM performance in the pre-, post-, and follow-up condition for group A, B and the Control group

	DR M (SD)	NR M (SD)	BlR M (SD)	VP M (SD)	BR M (SD)	LR M (SD)	SpS M (SD)
Group A							
Pre (*n* = 41)	20.3 (4.44)	13.9 (3.09)	27.4 (3.88)	16.7 (3.67)	11.7 (3.89)	12.2 (3.01)	17.2 (5.52)
Post (*n* = 41)	21.6 (4.86)	15.2 (3.40)	27.3 (3.86)	19.3 (4.35)	11.6 (4.31)	14.2 (3.69)	19.7 (6.27)
Follow-up (*n* = 39)	21.4 (5.52)	15.5 (4.12)	28.2 (4.53)	19.9 (4.82)	12.0 (5.21)	14.8 (4.53)	20.1 (6.26)
Group B							
Pre (*n* = 27)	20.4 (5.31)	14.6 (3.40)	26.1 (4.80)	15.6 (4.01)	12.2 (4.43)	12.2 (3.47)	16.8 (6.19)
Post (*n* = 26)	21.1 (4.86)	15.5 (3.50)	25.1 (4.31)	18.6 (4.12)	12.7 (4.72)	14.0 (3.17)	18.5 (5.32)
Follow-up (*n* = 25)	20.2 (4.65)	15.6 (3.46)	26.5 (4.77)	19.2 (4.28)	12.2 (5.07)	14.5 (4.78)	19.6 (5.54)
Control group							
Pre (*n* = 27)	20.2 (3.39)	13.9 (1.95)	25.9 (4.47)	15.6 (3.45)	12.3 (3.83)	12.1 (2.68)	17.0 (3.66)
Post (*n* = 26)	20.4 (3.59)	14.5 (2.14)	26.5 (4.41)	18.6 (3.64)	11.9 (4.31)	13.8 (2.65)	19.1 (5.71)
Follow-up (*n* = 25)	20.3 (4.32)	14.8 (3.64)	25.5 (4.22)	19.1 (5.38)	12.0 (4.73)	14.5 (2.80)	17.9 (5.78)

DR, Digit Recall; NR, Nonword Recall; BlR, Block Recall; VP, Visual Patterns Test; BR, Backward Digit Recall; LR, Listening Recall; SpS, Spatial Span; Ar, Arithmetic; Re, Reading; Sri, Story Recall immediate; SRd, Story Recall delayed; ST, Stroop test; R, Raven SPM.

Table 2b Mean scores (Standard Deviations) for secondary outcome measures in the pre-, post-, and follow-up condition for group A, B and the Control group

	Ar M (SD)	Re M (SD)	SRi M (SD)	SRd M (SD)	St M (SD)	R M (SD)
Group A						
Pre ($n = 41$)	71.2 (25.64)	65.5 (17.62)	11.0 (3.40)	8.9 (3.53)	46.0 (19.86)	35.4 (6.26)
Post ($n = 41$)	73.9 (26.19)	72.2 (18.14)	14.1 (4.31)	12.7 (4.36)	36.2 (16.55)	36.2 (5.99)
Follow-up ($n = 39$)	76.6 (25.24)	75.3 (18.74)	15.4 (5.04)	13.4 (5.19)	34.8 (18.40)	35.3 (7.30)
Group B						
Pre ($n = 27$)	82.6 (25.46)	74.1 (19.23)	11.2 (4.58)	9.8 (4.43)	45.9 (15.32)	32.7 (7.91)
Post ($n = 26$)	86.7 (25.54)	80.0 (19.55)	14.6 (5.32)	13.4 (5.76)	38.3 (14.61)	33.3 (7.57)
Follow-up ($n = 25$)	89.8 (28.89)	83.2 (20.76)	16.2 (5.92)	15.2 (6.39)	33.0 (12.87)	33.2 (8.13)
Control group						
Pre ($n = 27$)	73.6 (25.22)	68.2 (18.62)	11.1 (3.60)	9.4 (3.15)	45.7 (16.48)	33.4 (5.29)
Post ($n = 26$)	76.4 (23.98)	73.3 (19.0)	14.1 (4.03)	13.1 (4.10)	39.6 (17.47)	35.6 (6.99)
Follow-up ($n = 25$)	76.5 (25.48)	74.9 (19.43)	13.2 (4.03)	12.1 (3.82)	36.3 (20.07)	34.6 (7.73)

Ar, Arithmetic; Re, Reading; SRi, Story Recall immediate; SRd, Story Recall delayed; St, Stroop; R, Raven SPM.

Table 3 General linear model with contrasts between group A and group B versus the Control group for post-testing with pre-intervention score as covariate and for follow-up testing with post-intervention score as covariate with η_p^2, *B* and one-sided *p*

Compound measures		Pre to post			Post to follow-up		
		η_p^2	*B*	*p*	η_p^2	*B*	*p*
Verbal STM	Training A − Control	**.04**	**.17**	**.03**	.02	.16	**.12**
	Training B − Control	.00	.06	.28	.00	−.05	.62
Visual STM	Training A − Control	.00	−.02	.58	**.03**	**.19**	**.05**
	Training B − Control	.01	−.12	.84	**.04**	**.24**	**.03**
Verbal WM	Training A − Control	.00	.09	.24	.00	−.05	.62
	Training B − Control	.01	.15	.14	.01	−.12	.76
Visual WM	Training A − Control	.00	.81	.25	.02	1.57	.08
	Training B − Control	.00	−.20	.56	**.05**	**2.44**	**.02**
Scholastic abilities	Training A − Control	.00	.01	.45	**.04**	**.14**	**.03**
	Training B − Control	.00	.01	.43	**.05**	**.16**	**.02**
Story Recall	Training A − Control	.00	−.05	.58	**.05**	**.56**	**.02**
	Training B − Control	.00	−.02	.50	**.09**	**.85**	**.04**
Response inhibition	Training A − Control	.01	−3.48	.12	.01	3.22	.81
	Training B − Control	.00	−1.34	.34	.00	−.43	.46
Fluid intelligence	Training A − Control	.00	−.41	.62	.00	−.71	.30
	Training B − Control	.01	−1.57	.86	.01	−1.17	.23

η_p^2, Partial Eta squared: .01 = small effect, .06 = medium effect, .14 = large effect (Cohen, 1988). The lower the score on Response inhibition, the better the performance.

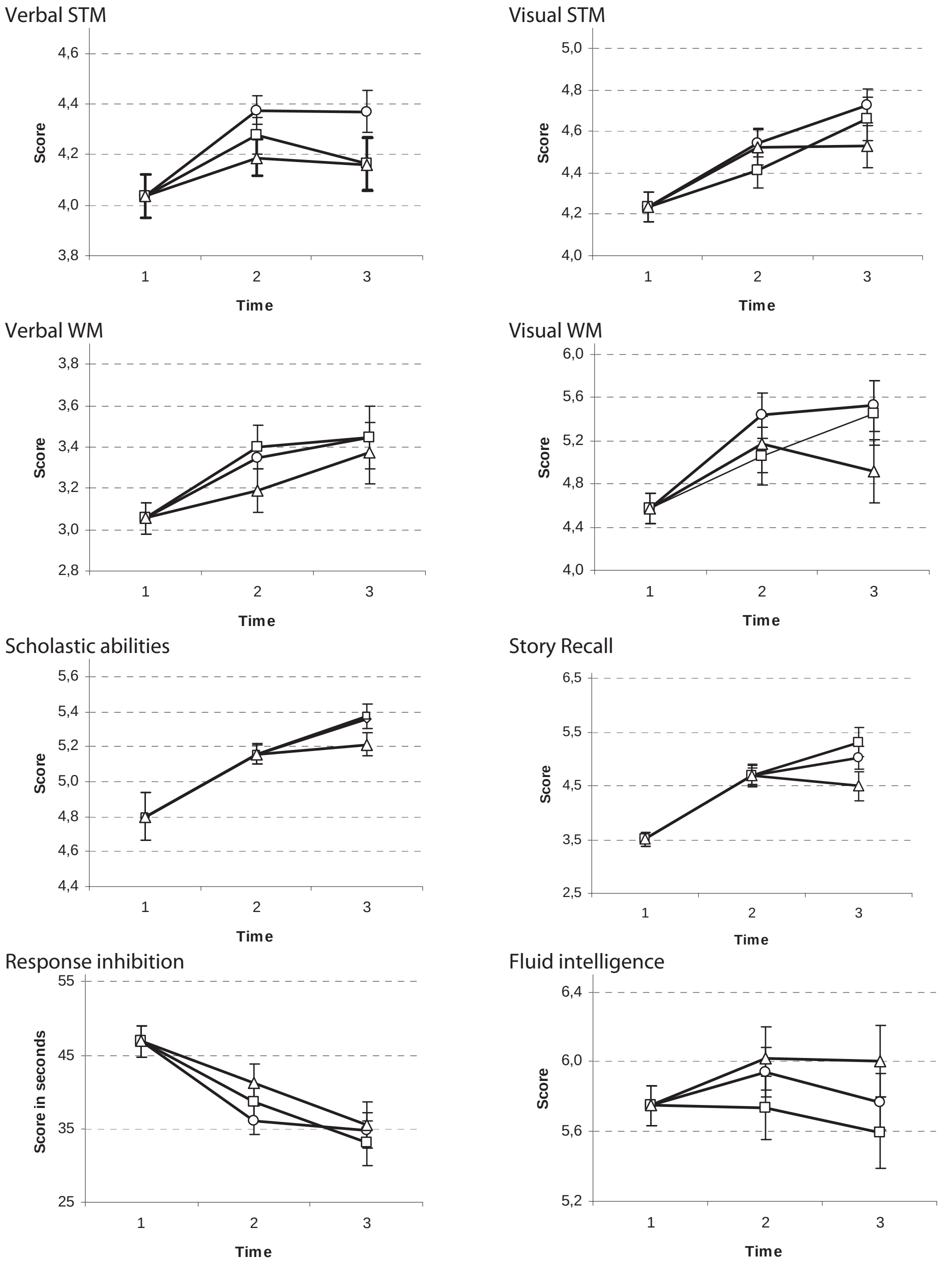


Figure 3 Adjusted mean with standard error at pre-testing (Time 1), post-intervention (Time 2), and at follow-up (Time 3) corrected for differences in baseline score, with the baseline score set to the common average for all groups.

from post- to follow-up test for group B. Scholastic abilities compound scores increased for both group A and group B compared to the Control group. In both cases, it was an increase in scores on the Arithmetic test (group A, $\eta_p^2 = .04$, $B = 3.45$, $p = .03$; group B, $\eta_p^2 =.06$, $B = 4.78$, $p = .01$) and not on the Reading test, which was responsible for the change. Finally, Story Recall compound score was higher (i.e. better) at follow-up than at post-testing for group A and for group B. Increases in both Story Recall Immediate and Story Recall Delayed were responsible for the change (group A respectively $\eta_p^2 = .05$, $B = 1.78$, $p = .02$ and $\eta_p^2 = .03$, $B = 1.36$, $p = .01$; group B respectively $\eta_p^2 = .08$, $B = 2.46$, $p = .005$ and $\eta_p^2 = .08$, $B = 2.48$, $p = .04$).

The increases in the different compound scores from post- to follow-up tests were also examined vis-à-vis the base-line (pre-testing). GLM analyses were run on follow-up scores with pre-test score as covariate. Group A had a higher visual WM (Spatial Span), compared to the Control group ($\eta_p^2 = .03$, $B = 2.23$, $p = .05$). Group A and group B obtained a higher compound score on Scholastic abilities (group A: $\eta_p^2 = .04$, $B = .16$, $p = .04$ and group B: $\eta_p^2 = .04$, $B = .19$, $p = .03$), caused by a higher score on the Arithmetic test (group A: $\eta_p^2 = .04$, $B = 3.45$, $p = .03$ and group B: $\eta_p^2 = .06$, $B = 4.78$, $p = .01$). Group A and group B did also obtain a higher mean Story Recall compound score (group A: $\eta_p^2 = .03$, $B = .58$, $p = .04$, and group B: $\eta_p^2 = .06$, $B = .84$, $p = .01$), caused by a higher score both on Store Recall Immediate (group A: $\eta_p^2 = .05$, $B = 1.78$, $p = .02$, group B: $\eta_p^2 = .08$, $B = 2.46$, $p = .04$) and Story Recall Delayed (group A: $\eta_p^2 = .03$, $B = 1.36$, $p = .05$, group B: $\eta_p^2 = .08$, $B = 2.48$, $p = .04$). Explorative GLM's were performed to investigate whether training A differed in outcome from training B. On none of the compound scores from pre- to post-testing and from post- to follow-up testing, significant differences were found between the two training groups.

In sum, looking at the immediate training effects (pre- to post-testing), group A showed an increase in verbal STM compared to the Control group. This gain was maintained at least till the follow-up session. Between post- and follow-up testing, group A and B showed an increase compared to the Control group on compound scores of visual STM, Scholastic abilities and Story Recall, while group B also improved on visual WM. Looking at effects from pre-intervention to follow-up, group A and group B obtained both higher scores on compound scores of Scholastic abilities and on Story Recall compared to the Control group, while group A additionally obtained a higher score on visual WM.

Discussion

The aim of this study was to evaluate the effectiveness of a WM training on memory, response inhibition, fluid intelligence, scholastic abilities and the recall of stories of children with MID.

The reliability of all administered tests was moderate till excellent. The moderate reliabilities refer to the WM tests. It is suggested that executive functioning tasks, like WM, are typically less reliable relative to tasks that don't place a demand on executive functioning, as executive functioning tasks are designed to tap processes invoked when handling new situations. Reliability should improve when administering these tasks repeatedly as novelty decreases (Pickering, 2006). Indeed, Table 1 shows higher reliabilities for WM at post-testing. However, when administered more often, the WM tests become less of a novelty, so although the reliability increases, validity might decrease (Pickering, 2006).

Most importantly, measures of verbal STM improved significantly, from pre- to post-testing in the group who received training A compared to the group receiving the Control training. Training B did not show any significant improvement on the outcome measures at post-testing. The beneficial effect of training A was maintained at follow-up. The post-test versus follow-up comparison yielded several significant differences. Group A and B both were better at follow-up then at post-intervention on measures of visual STM, scholastic abilities (arithmetic) and story recall (both immediate and delayed). In addition, group B, but not A, showed a significant increase in visual WM capacity. These effects were evaluated further by performing pre-test versus follow-up test comparisons. These comparisons indicated that scholastic abilities and ability to recall stories improved from pre- till follow-up testing both for group A and B but not for the Control group. In addition, when comparing between pre- and follow-up testing, it was group A that gained in visual WM capacity.

The observation that group A showed an increase in verbal STM performance from pre- till post-testing and group B did not, might be caused by the higher intensity of training A compared to training B. However, from post- till follow-up testing, group A and B both show increases on several outcome measures. In fact, increased effects at follow-up compared to immediate effects following WM training (Klingberg et al., 2005; Van 't Hooft et al., 2007) or effects only observable at follow-up (Klein & Boals, 2001) have been reported before. One possible reason for such a 'late' effect in the current study might be an overall lack of motivation by the children when faced with the tests for the third and fourth time (post-intervention testing). This might have dampened the results. At follow-up, approximately 10 weeks after finishing the training and the immediate post-testing sessions, the children probably have regained their interest in the tasks to such an extent that they were more likely to perform at their best. In addition, follow-up was also the time of the rewards; a little present, and a certificate, which might have motivated the children more. An alternative explanation for this 'late' effect might be the surpassing of a threshold; the children's WM gets a boost by the training which makes it possible for them to profit more from learning situations than they could before the training, hence, leading to higher scores at follow-up. This fanning out effect of the training is confirmed by the effects the training had on scholastic abilities, more specifically, on arithmetic. Although it is suggested that people with (mild) intellectual disabilities have difficulty generalizing what they have learnt (e.g., Bebko & Luhaorg, 1998; Park & Gaylord-Ross, 1989), it seems that our training has tapped and improved cognitive processes underlying these scholastic abilities. Indeed, the findings are in line with suggestions that when it is possible to train WM, it would affect also everyday tasks that are heavily depending on WM like arithmetic and other demanding academic activities (Klingberg et al., 2005).

An often heard comment on training effects in general, is that the apparent effectiveness of a training might be due to the control training being less challenging than the experimental training. In this study, however, we designed a control training as appealing as both training A and training B. The ratings from the children confirmed that the Control group children liked their training as much as the children in both training groups.

Although the visual WM training in this study showed positive effects on visual WM and other cognitive activities like arithmetic, it had no effect on verbal WM This is unfortunate as verbal WM especially is weak in children with MID (Maehler & Schuchardt, 2007; Van der Molen et al., submitted). Future research should reveal whether verbal WM training produces improved verbal WM performance in this population. A WM training for these children should then possibly comprise both visual and verbal WM as the visual WM training exerted its beneficial effect on an important target domain, i.e., scholastic abilities.

In line with the effects reported by Klingberg et al. (2005), we found effects on (verbal and visual) STM and on (visual) WM outcomes. However, in contrast to our study, their study showed additional effects on fluid intelligence and response inhibition, although only at immediate post-training assessment and not at follow-up assessment. The differences in those effects might be due to the higher intensity of their training, in total around 800 minutes, compared to ours, only around 90 minutes. In spite of the lower training intensity in our study, however, the current training did increase children's scholastic abilities and their ability to recall stories, outcome measures that were not included in the study of Klingberg et al. (2005). Furthermore, differences in outcomes between their study and ours might not be caused by their training per se, but rather by the intensity in combination with the type of children trained (ADHD versus MID). Indeed, in a study by Shavelson, Yuan, Alonzo, Klingberg, and Andersson (in press) middle school students were trained as in the study of Klingberg et al. (2005) including the same intensity. Interestingly, the trained students showed an increase on a Span-board task and on Digit Recall, described as STM tests, but they did not attain better scores relative to a control group on WM tasks and fluid intelligence. Shavelson et al. (in press) suggested that the children with ADHD in the study of Klingberg et al. (2005) are more susceptible to a WM training and its possible influence on fluid intelligence as WM is their weak point, whereas their students showed an average WM. It came as somewhat to a surprise that the long-term effects of training A and training B were largely comparable. The crucial difference between both training versions is the dynamic adjustment of training A to the child´s current performance In contrast, in training B, the child was only offered trials with one or two stimuli. It seems that demand per se, rather than exact load, is the beneficial ingredient of such a training in these children.

Finally, research should continue and explore this training strategy to increase the mnemonic abilities in this vulnerable group, as the results in the current study indicate that WM can be effectively trained in children with MID with positive effects on their scholastic abilities.

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6

Conclusions and general discussion

Introduction

The two main objectives of this thesis are a) to unravel working memory (WM) strengths and weaknesses in children with mild intellectual disabilities (MID), and b) to investigate if WM can be trained effectively in these children. Chapter 1 provides an introduction to the thesis and encompasses information about the concepts used in the subsequent chapters. Chapter 2 reports empirical data on the functioning of two components of Baddeley's WM model (1986): (1) the capacity of the phonological loop, also called verbal short-term memory (STM), and its automatic rehearsal capacity and (2) the central executive. Performance of children with MID (average chronological age of 15 years and an average IQ score of 70) was compared with typically developing children of the same chronological age (CA control; average chronological age of 15 years and an average IQ score of 100) and with younger, typically developing children of the same mental age (MA control; average chronological age of 10 years and an average IQ score of 100). In Chapter 3 verbal and visuo-spatial STM and WM in comparable groups was explored by use of an extensive task battery (see Chapter 1, Figure 1). Performance of children with MID was compared to that of the CA and MA control children. Furthermore, it was investigated if within the MID group subgroups exist with a unique WM profile each. Since WM is not only used in school based settings, but in everyday life as well, in Chapter 4 it was investigated how children with MID function on memory tasks in everyday life, and if those performances are related to their WM abilities. Finally, as WM is considered to be so important, it was investigated if WM can be trained effectively in children with MID. This is reported in Chapter 5.

In this sixth and final Chapter of the thesis, the results of the above studies will be summarized and integrated. First, the study outcomes will be briefly introduced and summarized. Next, the general conclusions of the thesis will be addressed in which the research questions posed in Chapter 1 will be answered. Returning issues that had to be dealt with, raised by the author, co-workers and reviewers will be considered subsequently. Finally, the implications of the results for practice and directions for future research are discussed.

Brief overview of findings

Background

WM is considered to be of great importance for the development of scholastic abilities (e.g., Gathercole & Alloway, 2006; Logie, 1993) and is related to fluid intelligence (e.g., Ackerman, Beier, & Boyle, 2005). It is a central construct within cognitive and experimental psychology (e.g. Shah & Miyake, 1999). Several WM models exist (for a review see Miyake & Shah, 1999), but probably one of the best known and most used in research is the one from Baddeley (1986, adapted and extended in 2000, originally Baddeley & Hitch, 1974). In this model WM consists of four components; 1) the visuo-spatial sketchpad (or visuo-spatial short-term memory, STM), 2) the phonological loop (or verbal STM), including an automatic rehearsal function, 3) an attentional control system and 4) the episodic buffer. As the episodic buffer is theoretically still in development it was not considered in this thesis. For more detailed information about any of the four components, see Chapter 1.

Study outcomes

First, the phonological loop and its automatic rehearsal were studied, as well as different functions of the central executive as described by Baddeley (1996; Chapter 2). Children with MID appear to be delayed on all tasks compared to CA control children. This is in line with other studies (e.g. Henry & MacLean, 2002; see also Bayliss, Jarrold, Baddeley, & Leigh, 2005). Compared to MA control children however, a mixed pattern of strengths and weaknesses can be observed. The capacity of the phonological loop (or verbal STM capacity) seems average to weak, as the children with MID perform worse on Digit Recall, but similar on Nonword Recall. However, the automatic rehearsal of incoming information, measured by use of the articulatory suppression effect and the word-length effect (Baddeley, 1986), was intact. This implies that although their verbal STM seems weak, children with MID do repeat incoming verbal information to prevent it from fading away. This finding was expected as automatic rehearsal is observed in typically developing children from 7 years on (Gathercole, Adams, & Hitch, 1994) and the 15-year-old children with MID in the current study had mental capacities comparable to 10-year-old typically developing children.

The central executive was examined with regard to four functions (Baddeley, 1996). The children with MID did less well on tasks measuring (1) retrieval and manipulation of information from long-term memory, (2) the inhibition of prepotent responses, and on tasks measuring (3) planning ability. In contrast, they did as well as the CA control children on the ability to (4) coordinate information from the visuo-spatial sketchpad and the phonological loop. This apparently deviant finding might be caused though by the relatively low demands of the dual-task (e.g. Bull & Scerif, 2001). However, the finding that children with MID did as well as the MA control children on all central executive tasks, implies that children with MID have an executive functioning conform their mental capacities.

Then, visuo-spatial and verbal STM and WM were assessed by the use of an extensive task battery (Chapter 3). Again, the children with MID performed less well on all tasks compared to the CA control children. Furthermore, the children with MID performed worse than the MA control children on Nonword Recall, indicating a verbal STM vulnerability. Note however, that in the first study the opposite was the case as the children with MID performed worse on Digit Recall and just as good on Nonword Recall. This might be a question of power, as the children with MID perform worse on both tasks in both studies. Visuo-spatial STM showed a fractionated pattern as well: on one of the tasks (Block Recall), the children with MID did worse than the MA control children, while they performed as well on the other visuo-spatial STM task (Visual Patterns test). There is some proof that Block Recall depends more on WM, instead of being a pure STM task (e.g. Vandierendonck, Kemps, Fastame, & Szmalec, 2004), which could be the reason why the children with MID performed worse on this task compared to the Visual Patterns test. However, this contrasts the finding that both groups performed similar on the Odd-One-Out task, a task specially designed to measure visuo-spatial WM. So, although we have arguments that this task is too simple to be qualified as a pure WM task (at least in regard to the verbal counter partners Listening Recall and Backward Digit Recall), it would be too easy to use this as the only explanation. Taking together these results, the most robust finding is the weakness the children with MID show on verbal WM; on both Listening Recall and Backward Digit Recall they perform worse than the MA control children. It seems that simultaneously storing and manipulating verbal information is difficult for children with MID, more difficult than would be expected on the basis of their mental capacities. This finding is in line with the results of a study on WM in 8-year-old children with MID (mean IQ score of 75; Maehler & Schuchardt, 2007). However, additional hierarchical cluster analyses indicated that within the MID group, subgroups exist with each their own STM and WM profiles. This includes also a group of children with a verbal WM comparable to that of CA control children.

Next, since WM is known to be important not only for scholastic abilities, but also for the successful implementation of complex cognitive activities in everyday situations outside the school class as well (Gathercole & Alloway, 2006; Logie, 1993), we wanted to see how children perform on everyday memory (EM) measures as EM is considered to be important for an adequate everyday functioning. Furthermore, we wanted to see if EM is related to WM in children with MID. We expected the children with MID to perform less well on EM measures than their typically developing peers. In addition, it was expected that the children with MID have to rely more on their WM while performing those EM tasks, as they are more demanding for them. Indeed, the results of that particular study (Chapter 4) show an overall delay for children with MID on EM tasks (subtest scores from the Rivermead Behavioral Memory Test; Wilson, Cockburn, & Baddeley, 1985) compared to CA control children. The children with MID did equally well as the MA control children on recognizing pictures and recalling a short story, but they did less well on the total screening score and on remembering a route. The delay in EM for children with MID was confirmed by their parents as they rated their child's memory as less good than did the parents of both the MA and CA control children. The children with MID themselves stated otherwise; they rated their own memory being as good as the MA and CA control children did rate their own memory. Probably, the children with MID did not compare their own memory functioning to that of typically developing children, but in regard to their own classmates; other children with MID. Another possible explanation is provided by Gilger (1992), who showed that the younger and the less intellectual capable, the less one is able to evaluate one´s own competencies.

Furthermore, for both the children with MID and the MA control children, but not for the CA control children, we found low to moderate ($.34 \leq r \leq .52$) correlations between RBMT indices and WM and STM test scores. Additional stepwise multiple regression analyses revealed that verbal STM tasks explained 12% to 16% of the variance in RBMT total score for both the MID group and the MA control group. Although we are cautious in the conclusions we can draw from these results, as the many correlations heightened the change to find significances, our expectations were confirmed. Indeed, everyday memory tasks might be more demanding for children with MID than is expected on the basis of their mental capacities. In addition, these demanding situations force them to use their WM. In contrast, typically developing children of the same age experience those daily situations more automatically, not needing to use their WM.

Finally, now that WM appeared to be weak in children with MID, the next question to be answered was if WM can be trained effectively. It is shown that this can be effectively trained in for example children with ADHD with an IQ score in the typical range (Klingberg et al., 2005). Therefore, an electronic WM training, the 'Odd Yellow' was developed[7] consisting of three versions, an adaptive, extensive version, a fixed, low intensive version and a control version. The training comprised 15 training sessions of each 6 minutes during 5 weeks. The effectiveness was measured with an extensive battery of STM, WM, executive and scholastic tasks, which was administered before and immediately after the training and at a 10-week follow-up. The results showed that the group who received the adaptive, extensive training had a verbal STM gain immediately after the training compared to the control group. Moreover, this effect remained and additional effects became visible from post testing till follow-up: both the extensive and 'low intensive' training groups showed a higher score on scholastic abilities and story recall and the 'low intensive' group also on visual WM compared to the control group.

General conclusions

The main outcomes of the studies in this thesis reveal a delay for children with MID on all STM, WM and EM measures compared to CA control children, except on a low control dual-task and recognizing pictures on which both groups perform comparable. The automatic rehearsal of information which can prevent verbal STM information from fading away is intact in children with MID. Compared to MA control children, the children with MID seem average on executive functioning, visual STM and visual WM, comparable to weak on verbal STM, and rather weak on verbal WM. This means that especially processing and manipulating of verbal information is difficult for children with MID. However, the finding of subgroups shows, for instance, that some children with MID do have an adequate functioning WM, while their STM is rather weak. Furthermore, everyday memory can be more challenging for children with MID than expected on the basis of their mental capacities. For example, they have problems with recalling a route (way finding). Both MID and MA children show some dependency on WM while performing EM tasks, while CA children do not. Finally, WM can be effectively trained in children with MID with a computerized program with effects beyond what was specifically trained, implying that cognitive abilities of children with MID can be improved.

In answer to the six research questions posed in Chapter 1:

1. *Do children with MID show a developmental delay or a deficit in STM and WM abilities? (Chapters 2 and 3)*

Children with MID perform, as expected, below the level of CA control children on verbal and visuo-spatial STM and WM, indicating a developmental delay. However, on some aspects children with MID show considerable weaker performance than MA control children indicating more than just a delay. Verbal STM, the ability to

[7] The training was programmed and designed by ShoSho, Amsterdam.

temporarily store and repeat incoming verbal information, seems more difficult for these children than expected on the basis of their mental capacities. Moreover, particularly verbal WM, the ability to store and manipulate verbal information, is weak and indicates a defect.

2. *Do children with MID show automatic rehearsal within the phonological loop? (Chapter 2)*

Yes, 15-year-old children with MID do show the automatic rehearsal of incoming verbal information.

3. *Do subgroups exist within the broader category of children with MID, each with their own specific STM and WM profiles? (Chapter 3)*

Yes, three subgroups can be distinguished on the basis of our data when looking at verbal and visuo-spatial STM and WM capacities. One group shows a delay on visual STM and a defect on verbal STM, verbal WM and on visuo-spatial WM. A second group shows a defect on verbal WM and a delay on the other memory aspects. A third group has average verbal STM and WM capacities, at the level of their chronological age, however, visual STM shows a defect.

4. *How do children with MID perform on EM tasks? (Chapter 4)*

Children with MID show a defect on a general index of EM. That is, they show difficulties with everyday memory tasks. Especially way-finding is difficult for them. However, they can remember a story as well as is expected on the basis of their mental capacities.

5. *Is EM related to WM in children with MID? (Chapter 4)*

Yes, it seems that children with MID rely on their WM capacities while performing EM tasks, probably more so than their typically developing peers.

6. *Can WM be effectively trained in children with MID and if so, does it affect other cognitive abilities? (Chapter 5)*

Yes, the computerized WM training 'Odd Yellow' which we developed for the purpose of this study showed positive effects. Increased performance is observed on verbal STM, visual WM, scholastic abilities and the recall of stories.

Challenges and limitations

Heterogeneous population

While carrying out the studies for this thesis, we were faced with different issues, which were difficult to solve. First of all, as discussed in the introduction to this thesis, children with MID form a heterogeneous population. Backgrounds and social-emotional aspects differ widely and probably the origin of the disability as well. A recent study showed that even after an extensive search of the causes of the retardation in Finnish children with an IQ score between 55 and 70, in 52% of the sample the cause remained unclear

(Heikura, Linna, Olsen, Hartikainen, Taanila, & Jarvelin, 2005). Unraveled causes were mainly genetic (27% of the cases), like chromosomal aberrations. This diversity and obscurity in origin of the retardation could probably well be one of the main reasons for researchers to be hesitant about studying the development of children with MID, hence leading to a limited number of publications (see Chapter 1). Although we excluded children diagnosed with ADHD and PDD-NOS, as both are known to be associated with their own unique WM profiles, the remaining group of children with MID is still heterogeneous (also illustrated by the observation of different clusters in Chapter 3), which makes the results more difficult to generalize than are the results of a more homogeneous group like children with Down syndrome. In an effort to tackle this problem, additional analyses were performed on all measures with behavioral problems, indexed by use of the Teacher Report Form (TRF; Achenbach, 1991), as a covariate.[8] The outcomes of these analyses were hardly any different from the original analyses, indicating that the presence of behavioral problems in children with MID do not affect their cognitive abilities as measured in this thesis. However, it should be noted that we excluded children with MID co-morbid for ADHD (prevalence reported to be around 14.8%; Dekker & Koot, 2003) and co-morbid for PDD-NOS (prevalence reported to be around 1.5%; Dekker & Koot, 2003). In future research, it would be interesting to assess children with MID including children with psychiatric diagnosis and then to compare the different subgroups. By doing so, we then learn if it is the intellectual retardation or the psychiatric disorder that mostly determine the results.

IQ ranges

In our studies, the IQ scores of children with MID ranged between 55 and 85. The chosen range regularly led to comments by reviewers abroad, most notably by reviewers from American journals. They placed question marks by the chosen range, as the American Association on Intellectual and Developmental Disabilities (AAIDD, formerly known as the American Association on Mental Retardation, AAMR; Luckasson et al., 2002) separate people with an IQ score between 55 and 70/75, described as mildly intellectually disabled, from people with an IQ score between 75 and 85, the so-called borderline intellectually disabled. Our arguments, that in Dutch residential care and education the range 55 – 85 is commonly used because all children within that range having additional behavioural problems profit from respectively its care and curriculum (e.g. Verstegen, 2005), did not always convince the reviewers. This made it necessary for us, for example, to restrict the range to 55 – 75 in Chapter 4, and to additional MANCOVA's in Chapter 5.[9] Analyses in which we compared the lower IQ range (55 – 75) with the higher IQ range (76 – 85) led to new challenges: what if both groups do not differ statistically significant from each other on the outcome measures, which was mostly the case, but both are differently related to the control groups? Some analyses showed indeed that the lower IQ range children scored significantly lower

[8] These MANCOVAs are not always reported in the Chapters, but see Chapter 4.

[9] Note however that the IQ score range 85 – 115 is considered to represent typically developing children which consists of two standard deviations as well, like in the 55 – 85 IQ score range.

than the CA control group, while the higher IQ range children did not, however, both MID groups did not differ statistically significantly from each other. Do both MID groups then perform similar or not? As Gelman and Stern (2006) put it elegantly *"The difference between "significant" and "not significant" is not itself statistically significant"* (Gelman & Stern, 2006, p. 328), meaning in this case, that the higher IQ range group is considered to perform comparable to the lower IQ range group even when the performance of both groups is differently related to the CA control group.

Practical implications and future research

This study on WM in children with MID is one of the few studies that focuses on the cognitive abilities of children with MID and on the possibilities of improving these abilities. This is illustrated by the directors of the schools for special education participating in the study as they motivated their willingness to facilitate participation of their pupils often by saying that hardly anything is done and developed for these children from a scientific perspective. This lack of knowledge forces schools for special education to develop didactic methods without theoretical bases. This is unfortunate as it makes it difficult to attune to the abilities and the possibilities of these children.

This thesis tries to unravel the STM and WM strengths and weaknesses in 15-year-old children with MID. The insights give many tools to communicate more effectively with these children. For example, when WM deficits are clear, it is suggested to speak in short, well structured sentences, using few difficult words and repeating the instructions (Alloway & Gathercole, 2006; Gathercole, Lamont, & Alloway, 2006). Furthermore, it gives insight in the children's behaviour. That is, children who might seem to be disobedient, or not willing to follow the instructions, might simply have forgotten what they had to do, or in which order. Children with severe WM problems will show great difficulty in monitoring a group conversation, or participate in it as the communication goes too fast and probably often disorganized (Alloway & Gathercole, 2006; Gathercole et al., 2006). So, they might sit silently, just watching the conversation going on and possibly give the impression to be shy, uninterested, unwilling to listen or to be a daydreamer. Therefore, it is considered that a good STM and WM screening at the beginning of the school career is of great importance (not only for children with disabilities, but for typically developing children as well, e.g., Alloway & Gathercole, 2005). After all, WM is considered to be very important, like Alloway (2008, ¶12) states:

> *'It is a much more important predictor of learning than IQ because it measures a child's potential to learn rather than having any link to environment or socio-economic background, which are closely linked to IQ."*

Before such a screening is possible, it is necessary to develop a Dutch test battery, for example by translating the Automated Working Memory Test Battery by Alloway (2007) and validating and standardizing it for the Dutch population. In addition, it is not known if STM and WM in children with MID develops in the same way as in the typically developing population. In line with the 'developmental delay' theory (see Chapter 1), it can well be that memory aspects take longer to develop, or either, come to a hold at an earlier age. At present, we are conducting a study to see how STM and WM develop in children with MID between 10 and 15 years old. The preliminary results indicate that the development of verbal STM comes to a hold before or at 10 years of age, while visuo-spatial STM and WM develops at least till the children are 15-years old. More research on the development in these children, with more age groups and starting at a younger age is recommended so as to see how their development progresses. Insight can lead to appropriate intervention at the right time. Furthermore, it would be interesting to include children with an IQ score between 55 and 85 who follow regular education (and hence are in general not classified as having MID, see Chapter 1) to investigate what makes them being able to follow regular education as opposed to the children with an IQ score in the same range following special education. Is the second prerequisite for the definition 'MID'; problems with adaptive behavior skills, the predictor (or mediator)? Or, do the children in the regular setting have an extraordinary WM? Other causes might be plausible and detecting them might again lead to interventions or support so as to add to the development of children with MID.

The training (Chapter 5) 'Odd Yellow' sorted positive effects. This means that the abilities and skills of children with MID are not unalterable and can be positively affected by training underlying cognitive abilities. However, before looking at the implementation possibilities, the study should be replicated to prove its reliability. In addition, the effect of the training should be investigated in younger children with MID, as the earlier they can start with such a fundamental cognitive training, probably the more and longer the children are likely to profit from its effect. Also, the training should be tested with different intensities. In our study effects were notable after 15 sessions of each 6 minutes training. Possibly, after a more intensive training, the effects might be even bigger and / or more widespread. When the training proves to be reliably effective, it would be of value to implement it on a structured basis within the school curriculum especially because it shows generalizing effects. The results of the 'Odd Yellow' suggest that cognitive abilities of children with MID can be improved which should encourage researchers to further explore the training of other important basic cognitions, like for example attention.

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Samenvatting

Inleiding

Binnen de populatie kinderen[10] met een verstandelijke beperking, vormen kinderen met een lichte verstandelijke beperking (LVB) de grootste groep. Het is dan ook verbazingwekkend dat juist bij deze kinderen zo weinig onderzoek gedaan wordt. De resultaten van studies die zich wel gericht hebben op deze kinderen lijken onder meer te wijzen op een zwak werkgeheugen. Onder werkgeheugen wordt het gelijktijdig opslaan en bewerken van informatie verstaan. Een voorbeeld van een werkgeheugentaak is het uit het hoofd maken van een rekensom '12 + 9 – 5'. Terwijl een kind de bewerkingen uitvoert, moeten de getallen en tussenoplossingen onthouden worden. Omdat het werkgeheugen zo belangrijk is voor bijvoorbeeld de ontwikkeling van schoolse vaardigheden, worden in de studies beschreven in dit proefschrift het kortetermijngeheugen en werkgeheugen van kinderen met een LVB onderzocht. De prestaties van deze kinderen worden vergeleken met die van gemiddeld begaafde kinderen. Daarnaast wordt ook het functioneren van het dagelijks geheugen, het geheugen zoals dat in het dagelijks leven gebruikt wordt, onderzocht. Tenslotte is er een gecomputeriseerde werkgeheugentraining ontwikkeld en aangeboden aan een grote groep kinderen met een LVB, waarbij gekeken is naar de effecten ervan op het werkgeheugen en op gerelateerde cognitieve vaardigheden.

Aan de studies doen gemiddeld 15-jarige kinderen met een LVB mee, met een IQ-score tussen de 55 en de 85[11] en tekorten in of beperkingen van het huidige aanpassingsgedrag (zoals bijvoorbeeld communicatie, sociale vaardigheden, zelfverzorging en functionele intellectuele vaardigheden). Zij volgen allen Praktijkonderwijs. Kinderen met Pervasieve ontwikkelingsstoornissen (PDD) en/of een Aandachtstekortstoornis met hyperactiviteit (ADHD) zijn uitgesloten van de studies omdat deze stoornissen gekenmerkt worden door eigen specifieke werkgeheugenprofielen die het werkgeheugenprofiel van kinderen met een LVB kunnen verstoren. De prestaties van kinderen met een LVB worden in dit proefschrift steeds vergeleken met die van twee groepen controlekinderen. De CA ('chronological age') controlegroep bestaat uit gemiddeld begaafde leeftijdsgenoten (gemiddelde IQ-score is 100, gemiddelde leeftijd is 15 jaar) en de MA ('mental age') controlegroep bestaat uit jongere, gemiddeld begaafde kinderen (gemiddelde IQ-score is 100, gemiddelde leeftijd is 10 jaar) met vergelijkbare mentale capaciteiten als die van de kinderen met een LVB.

Werkgeheugen

Het werkgeheugen wordt verondersteld van groot belang te zijn voor de ontwikkeling van schoolse vaardigheden. Er bestaan meerdere werkgeheugenmodellen, maar dat van Baddeley is waarschijnlijk het meest bekende en het meest gebruikt in studies. In dit model is het werkgeheugen opgesplitst in vier componenten: (1) Het visuo-spatiële schetsblok en (2) de fonologische lus zijn verantwoordelijk voor de tijdelijke opslag van respectievelijk visuo-spatiële en verbale informatie (ofwel visuo-spatiële kortetermijngeheugen en verbale kortetermijngeheugen). De fonologische lus heeft ook een functie voor het automatisch herhalen waarmee voorkomen wordt dat binnengekomen informatie uit de tijdelijke opslag verdwijnt. Beide zogenoemde 'slaafsystemen' worden aangestuurd door (3) de centrale aanstuurder, een

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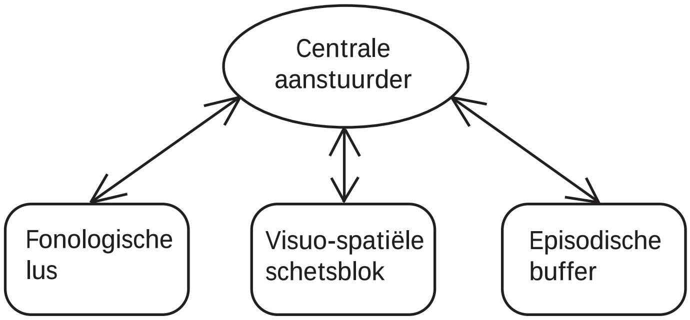
[10] Met 'kinderen' worden kinderen en jongeren bedoeld.

[11] De kinderen die in Hoofdstuk 4 beschreven staan hebben een IQ-score in de range 55 – 75. Dit op verzoek van het Amerikaanse tijdschrift waar de studie ter publicatie is aangeboden.



Figuur 1 Baddeley's werkgeheugenmodel.

aandacht- en controlesysteem. Taken die zowel een beroep doen op het kortetermijngeheugen (KTG) als op de centrale aanstuurder worden werkgeheugentaken genoemd. In (4) de episodische buffer, aangestuurd door de centrale aanstuurder, kan geïntegreerde informatie uit verschillende modaliteiten (verbaal en visueel) opgeslagen worden zowel komend vanuit het langetermijngeheugen als uit het KTG. Omdat er nog maar weinig onderzoek gedaan is naar de episodische buffer en er ook verder weinig over bekend is, is deze component niet als variabele in één van de studies betrokken. Zie Figuur 1 voor een schematische weergave van de vier componenten.

Resultaten

Studie 1

In de eerste studie (beschreven in Hoofdstuk 2) wordt de capaciteit van de fonologische lus (ofwel verbale KTG) en de functie informatie automatisch te herhalen onderzocht, evenals verschillende functies van de centrale aanstuurder. Kinderen met een LVB ($n = 50$) presteren op verbale KTG-taken minder goed dan CA controlekinderen ($n = 25$). In vergelijking met de MA controlekinderen ($n = 25$) zijn de uitkomsten minder eenduidig. Bij de kinderen met een LVB geldt dat hun capaciteit van de fonologische lus net zo groot is of wat beperkter (afhankelijk van de test) ten opzichte van de MA controlekinderen. De functie van de lus om informatie automatisch te herhalen is intact. De centrale aanstuurder is gemeten aan de hand van de vier functies zoals beschreven door Baddeley. De kinderen met een LVB presteren minder goed dan de CA controlekinderen op de functies (1) 'ophalen en bewerken van informatie uit het langetermijngeheugen', (2) 'response inhibitie' en (3) 'planningsvaardigheden'. Beide groepen presteren daarentegen wel even goed op de functie (4) 'aansturing van het visuo-spatiële schetsblok en de fonologische lus'. Op basis van deze resultaten concluderen wij dat het functioneren van de centrale aanstuurder bij kinderen met een LVB vergelijkbaar is met dat van (ongeveer 5 jaar) jongere, normaal begaafde kinderen.

Studie 2

In de tweede studie (zie Hoofdstuk 3) is het visuo-spatiële en verbale KTG en het werkgeheugen onderzocht met een uitgebreide testbatterij. In deze studie presteren de kinderen met een LVB ($n = 49$) op alle taken minder goed dan de CA controlekinderen ($n = 39$). Ten opzichte van de

MA controlekinderen (n = 29) is er weer een minder eenduidig patroon te zien. De kinderen met een LVB doen het minder goed op één van de twee verbale KTG-taken, op één van de twee visuele KTG-taken en op beide verbale werkgeheugentaken dan de MA controlekinderen. Hiermee lijkt de meest robuuste bevinding te zijn dat de kinderen met een LVB een zwak verbaal werkgeheugen hebben. Het gelijktijdig opslaan en bewerken van verbale informatie is voor hen moeilijker dan verwacht op basis van hun mentale capaciteiten. Echter, clusteranalyses laten een diversiteit aan cognitieve mogelijkheden zien. Binnen de groep kinderen met een LVB bestaan subgroepen met elk een eigen specifiek werkgeheugenprofiel waaronder een subgroep met juist een sterk verbaal werkgeheugen, functionerend conform hun chronologische leeftijd.

Studie 3

Het werkgeheugen is niet alleen van belang voor de ontwikkeling van schoolse vaardigheden, maar ook voor een correcte uitvoering van allerlei dagelijkse geheugentaken buiten het klaslokaal. Daarom wordt in de derde studie (Hoofdstuk 4) onderzocht hoe kinderen met een LVB functioneren op dagelijkse geheugentaken en of die prestaties samenhangen met hun werkgeheugen. De kinderen met een LVB (n = 39) presteren minder goed op de alledaagse geheugentaken dan de CA controlekinderen (n = 39), maar op een visuele herkenningstaak laten zij vergelijkbare prestaties zien. Ten opzichte van de MA controlekinderen presteren de kinderen met een LVB (n = 26) net zo goed op die visuele herkenningstaak en op het onthouden van een kort verhaaltje, maar ze doen het minder goed op een taak waarin een route onthouden moet worden.

Bij de kinderen en bij hun ouders zijn ook vragenlijsten afgenomen ter beoordeling van hun eigen geheugen, respectievelijk van dat van hun kind. De ouders van de kinderen met een LVB bevestigen het beeld van een zwak dagelijks geheugen; zij vinden het geheugen van hun kind slechter dan de ouders van de gemiddeld begaafde kinderen dat vinden van hun kind. De kinderen met een LVB zelf beoordelen hun dagelijks geheugen net zo positief als de controlekinderen. Waarschijnlijk vergelijken zij hun eigen geheugen met dat van hun klasgenoten, ook kinderen met een LVB.

Zowel in de groep kinderen met een LVB als de MA controlekinderen wordt een verband gevonden tussen scores op de dagelijks geheugentaken en de werkgeheugentaken (correlaties: $.34 \leq r \leq .52$). In de CA controlegroep worden geen betekenisvolle correlaties gevonden. Aanvullende regressie-analyses laten zien dat scores op de verbale KTG-taken 12% tot 16% van de variantie van de RBMT totaalscore verklaren voor zowel de kinderen met een LVB als voor de MA controlegroep. Ondanks het risico op kanskapitalisatie (een grote hoeveelheid correlaties is bekeken) bevestigen de uitkomsten onze vermoedens dat kinderen met een LVB dagelijks geheugentaken over het algemeen moeilijker vinden dan normaal begaafde kinderen en dat zij waarschijnlijk daarom ook vaker een beroep moeten doen op hun werkgeheugen bij het uitvoeren van die dagelijks geheugentaken.

Studie 4

Uit de resultaten tot nu toe blijkt dat vooral het werkgeheugen van de kinderen met een LVB zwak is, vermoedelijk onder andere tot uiting komend in een zwak dagelijks geheugenfunctioneren. In de communicatie met deze kinderen moet daarom rekening gehouden worden met de werkgeheugenbelasting, zowel in een gesprek als bijvoorbeeld bij instructies. Dat betekent communiceren in korte zinnen, de opdrachten in een duidelijke structuur aanbieden, het herhalen van opdrachten en bijvoorbeeld het nagaan of het kind de opdracht goed begrepen en onthouden heeft. Behalve dat de omgeving rekening kan houden met het zwakke werkgeheugen van kinderen met een LVB, is in deze studie (zie Hoofdstuk 5) nagegaan of het werkgeheugen effectief te trainen is. Enkele onderzoeken hebben laten zien dat het werkgeheugen bij andere populaties wel degelijk te trainen is, bijvoorbeeld bij gemiddeld begaafde kinderen met ADHD. In deze studie hebben we daarom een gecomputeriseerde werkgeheugen-training ontwikkeld,[12] de 'Raar maar waar training' en aan 95 kinderen met een LVB aangeboden. De training bestaat uit drie versies, een adaptieve (intensieve) versie, een niet-adaptieve (laag-intensieve) versie en een controleversie. De training bestaat uit 15 sessies van elk 6 minuten verdeeld over 5 weken. De effectiviteit van de training wordt in kaart gebracht door de afname van een uitgebreide testbatterij vooraf en meteen na afloop van de training en tien weken na afloop van de training. De resultaten laten zien dat de groep die de intensieve training gevolgd heeft ($n = 41$) een beter verbaal KTG heeft dan vóór de training in vergelijking met de controlegroep ($n = 27$), zowel meteen na afloop van de training als na tien weken. Verder laten de kinderen van de intensieve en van de laag-intensieve training ($n = 27$) resultaten zien die pas bij de follow-upafname, tien weken na de training, effectief blijken te zijn. In vergelijking met de kinderen die de controletraining hebben gevolgd, blijken de beide trainingsgroepen dan een hogere score te hebben op taken voor schoolse vaardigheden en het onthouden van een verhaaltje (zowel ten opzichte van hun scores van vóór de training als van onmiddellijk na de training).

Algemene conclusies van dit proefschrift

Kinderen met een LVB doen het minder goed dan CA controlekinderen op vrijwel alle KTG-, werkgeheugen- en dagelijks geheugentaken. Zij kunnen wel net zo goed binnenkomende visuo-spatiële en verbale informatie coördineren (een taak van de centrale aanstuurder) en plaatjes herkennen (een dagelijks geheugentaak). Het automatisch herhalen van informatie, wat voorkomt dat informatie uit het verbale KTG verdwijnt, is intact bij kinderen met een LVB.

De kinderen met een LVB presteren conform hun mentale capaciteiten op taken van de centrale aanstuurder, het visuo-spatiële KTG en het visuo-spatiële werkgeheugen. De kinderen met een LVB presteren gemiddeld tot wat zwakker dan MA controlekinderen op verbale KTG-taken en beduidend zwakker op verbale werkgeheugentaken. Dit betekent dat vooral het tegelijkertijd opslaan en bewerken van verbale informatie moeilijk is voor deze kinderen. Maar, dit geldt niet voor alle kinderen met een LVB, want de resultaten tonen aan dat er een subgroep is met juist een sterk ontwikkeld verbaal werkgeheugen.

Verder blijken dagelijks geheugentaken moeilijker te zijn voor kinderen met een LVB dan verwacht op basis van hun mentale capaciteiten, zo hebben ze moeite met het onthouden van een route. Zowel kinderen met een LVB als MA controlekinderen zijn in een bepaalde mate afhankelijk van hun werkgeheugen bij het uitvoeren van dagelijks geheugentaken. CA controlekinderen tonen die afhankelijkheid niet, het lijkt erop dat de uitvoering bij hen geautomatiseerd verloopt.

Tenslotte, het werkgeheugen van kinderen met een LVB lijkt met een computerprogramma effectief trainbaar te zijn. Het laat zowel positieve effecten zien op het KTG, het werkgeheugen, de schoolse vaardigheden, als het onthouden van een verhaaltje.

[12] De training is geprogrammeerd en ontworpen in samenwerking met ShoSho, Amsterdam.

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Curriculum vitae

Mariët van der Molen was born in Harderwijk, The Netherlands, on August 7, 1972. After finishing secondary school (VWO) in 1991, she lived and worked for two years in Paris, France, and Sydney, Australia in communities of L'Arche, an international organization for people with developmental disabilities. In 1993, she started her study Developmental Psychology at the University of Amsterdam. After her graduation in 1998, she worked as a researcher at Groot-Emaus, Ermelo, The Netherlands (recently known as Kwadrant, 's Heeren Loo Zorggroep), an institution for youth with mild intellectual disabilities. The year following, she worked as a psychologist in the same institution, later on in combination with a three year during position as staff member and coordinator of project groups at the Landelijk Kenniscentrum LVG of the Vereniging Orthopedagogische Behandelcentra, a central knowledge centre of the Dutch institutions for youth with mild intellectual disabilities. Since 2000, she regularly gives lectures and courses at the Saxion Hogeschool in Deventer, the University of Amsterdam, and the Post Academisch Onderwijs in Driebergen, which provides university post master courses. From 2001 till 2004, she was a lecturer and coordinator of courses on intervention and diagnostics at the Department of General and Special Education of the Utrecht University, where she also obtained her qualification as university teacher (BKO). At 2004 she started her PhD project at the same department. She is a member of the editorial staff of the journal Onderzoek en Praktijk. Since December 2008, Mariët works as assistant professor at the department of developmental psychology, University of Amsterdam. Mariët is married to Erik and has three children, Teun, Roos and Gijs.

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