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Self-reported memory strategies and their relationship to immediate and delayed text recall and working memory capacity

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Abstract

The aim of this study was to examine the performance of fifth-grade children in the reproduction of the content of a new text directly after they had read it (immediate recall) and one week later (delayed recall), as well as to investigate the relationship between performance, self-reported memory strategies, and working memory capacity (WMC). The results revealed that more complex strategies are associated with better performances, and that children with a high WMC outperformed children with a lower WMC in immediate and delayed text recall tasks. Hierarchical regression analyses showed that memory strategy and WMC are the strongest predictors for both immediate and delayed recall tasks. It is argued that one can use self-reported memory strategies to estimate strategy proficiency. Awareness of the importance of memory strategies and children's WMC in education are further discussed.

Keywords: working memory capacity, self-reported memory strategies, children, text recall

It is well established that working memory capacity (WMC) and its executive functions are significant predictors for specific school performances such as literacy, vocabulary and mathematics (e.g. Alloway et al. 2009, 606–621; Andersson and Lyxell 2007, 197–228; Gathercole and Pickering 2000a, 377–390; Hitch et al. 2001, 184–198), and that it mediates the development of memory strategies which, in turn, affects scholastic attainment (e.g. Adams and Hitch 1997, 21–38; Beilock and DeCaro 2007, 983–988; Turley-Ames and Whitfield 2003, 446–468). Working memory (WM) includes an attentional executive system controlling three separable but interacting subsystems: the phonological loop, the visuo-spatial sketchpad, and the episodic buffer (Baddeley 2000, 417–423). Working memory capacity (WMC) refers to the ability to process and store information simultaneously (Baddeley 2010, 136–140; Beilock and DeCaro 2007, 984; Turley-Ames and Whitfield 2003, 446). It has a linear development from the age of four throughout adolescence (Gathercole et al. 2004, 177–198), but varies widely across individuals (Broadway and Engle 2011). Individual differences in WMC arise from differences in the ability to actively maintain, manipulate and access task-relevant information in the face of potentially

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interfering distraction (Unsworth and Engle 2007, 104–132). Memory strategies are deliberate mental activities designed to enhance encoding and retrieval, and refer to any of a broad set of helpful techniques to improve recall of what has been learned. Such strategies range from external aids (e.g. note-taking, use of a daily planner) to internal memory strategies (e.g. chunking, visualisation) and have been found to aid long-term memory formation (Carney 2011, 937–938). The development of memory strategies is suggested to be more abrupt than gradual (Schlagmüller and Schneider 2002, 298–319; Schneider et al. 2004, 193–209), with the progression from no use of memory strategies to the use of such strategies occurring as a rapid transition for most children (Schneider et al. 2009, 70–99). In the present study, children's self-reported memory strategies in reading and reproducing a novel text are explored, and the relations to WMC studied.

The effectiveness of memory strategy is evident from 7 years of age, and the use of effective memory strategies and performance in text recall tasks seems to increase significantly between the ages of seven and ten (Schneider et al. 2009, 70–99). However, task difficulty influences progress; that is, when tasks are more cognitively demanding, progress tends to be less rapid. It has also been shown that utilising memory strategies during encoding will affect later performances (Hasselhorn 1992, 202–214). In addition, the use of multiple strategies increases as a function of age which additionally improves recall ability (Coyle and Bjorklund 1997, 372–380). There is substantial support for the claim that the acquisition of memory strategies depends on WMC (e.g., Adams and Hitch 1997, 21–38; Bjorklund et al. 1997, 411–441; Pressley and van Meter 1993, 128–165); therefore, when investigating memory strategies it is critical to consider individual variation in WMC in relation to the ability to produce and execute such strategies. This is particularly important when faced with tasks such as free recall (Guttentag 1989, 146–170) where memory strategies to encode and retain information require high-level mental resources. Studies have also shown that children with a lower WMC, besides having a short attention span and being easily distracted, experience additional problems in monitoring the quality of their work (Gathercole et al. 2008, 214–223). Monitoring is a regulatory component responsible for selecting those memory strategies that work, and then modifying them, or implementing new ones (Joyner and Kurtz-Costes 1997, 275–300).

This regulatory component is partly dependent on task specificity and context, but mainly on WMC. In line with this, several studies have shown that individuals with a high WMC use more elaborate and more cognitively demanding memory strategies, and therefore perform better. In a study of 7- to 11-year-old children (Adams and Hitch, 1997, 21–38), it was demonstrated that a higher WMC was associated with more sophisticated memory strategies and more advanced arithmetic, whereas a lower WMC was associated with less sophisticated memory strategies, and less advanced arithmetic. Beilock and DeCaro (2007, 983–998) showed that individuals with a higher WMC used more complex memory strategies compared with their counterparts with a lower WMC. Turley-Ames and Whitfield (2003, 446–468) confirmed that the use of more elaborate memory strategies was more prominent and effective for individuals with a high WMC and, conversely, that less cognitively demanding memory strategies were more effective for individuals with a low WMC. In line with this evidence, Lemaire and Lecacheur (2011, 282–294) found increased efficiency in executive function in seventh graders to be significantly related to children's strategy selection. Recently, Schleepen and Jonkman (2012, 265) suggested that children's individual WMC is an important determinant of the development of successful use of more effort-demanding semantic grouping strategies (i.e. grouping items into subcategories) during both encoding and retrieval.

If children do utilise strategies, there is also a question of the relationship between the possession of knowledge about how to use strategies during encoding for later recall and being able to name them. In a study by Whitebread et al. (2009, 63–85), 3- to 5-year-old children demonstrated awareness of cognitive processes during problem-solving, both verbally and non-verbally. Henry and Norman (1996, 177–199) studied the performance of 4- and 5-year-old children in a free recall task, their use of strategies for encoding and later recall of the material, and their ability to verbalise their memory strategies. Their results showed that children at the age of 4 to 5 years could already verbalise the relationship between their knowledge of simple strategic behaviour such as naming, and their use of that strategy. Justice (1985, 1107) showed that at about 7 years of age, children seem to develop an awareness of the value of strategy use in learning. At this age, most children spontaneously generate typical strategies like rehearsal to improve learning without the instruction of adults (Paris et al. 1982, 490–509). There is also evidence of progression; for example, Eileen (1978, 257–266) found that, in comparison with children in the first and third grades, fifth graders could verbally reflect on the usefulness of their memory strategies during encoding for later recall. Several researchers agree that the development of metacognition increases with age (Cross and Paris 1988, 131–142; Kuhn and Dean 2004, 268–273; Schneider 2008, 114–121; Schraw and Moshman 1995, 351–371). Similarly, Bjorklund and Zeman (1982, 799–810) showed in three experiments that fifth graders were able to identify and name their own strategies when asked to recall the names of their classmates, and they also performed better compared to younger children (see Schneider et al. (2009, 70–99) and Joyner and Kurtz-Costes (1997, 275–300) for a review). Metacognition is a multifaceted concept; however, in the present study we narrow the definition of metacognition down to the ability to verbally report the use of a particular memory strategy for a specific task.

One way in which teachers and parents facilitate cognitive development is by nurturing the development of children's understanding about and application of memory strategies. The awareness of their strategies enables children to benefit from instruction, which in turn facilitates more durable strategy transfer (see Carr et al. 1989, 765–771, for a review). By the time children reach middle school they are expected to be able to gain meaning from texts. Remembering text (words or sentences) requires a child to first register speech-like memory traces and through a process of subvocal rehearsal store the information in long-term memory (Baddeley 2010, 136–140) and, second, to recall the words or sentences in the correct order and process the meaning of those words or sentences; a task that requires both the executive functions of WM and the phonological loop responsible for the storage of language-based material (Gathercole and Pickering 2001, 89–97). Although aspects such as making inferences, drawing conclusions, predicting outcomes and recalling specific details are additive metacognitive aspects for reading comprehension (e.g. Sencibaugh 2007, 6–22), the present study restricts its focus to self-reported memory strategies and text recall in relation to WMC.

Inferred from above it is reasonable to argue that children in grade 5 (11–12 years of age) should be able to report on their memory strategies. On the contrary, if they do not report using strategies they should be considered at risk of not having acquired any strategies. Memory strategies can provide scaffolding and reduce WM load, therefore helping to avoid the occurrence of WM-related failures (McMurray 2011, 155). Thus, the use of strategies can make remembering less difficult, i.e. promote long-time learning (Lai 2011). It is therefore important from a pedagogical perspective to investigate if children's self-reports can be seen as indicative of whether the reported strategies are actually utilised or not, and if this utilisation, in turn, is predictive of school attainment.

In summary, several studies have shown that children are able to reflect with accuracy on and theorise about their own thinking (Bjorklund and Zeman 1982, 799–810; Lai 2001), and that WMC is essential for developing strategies (e.g. Adams and Hitch 1997, 21–38; Bjorklund et al. 1997, 411–441; Pressley and van Meter 1993, 128–165). Thus, we argue that if self-reported strategies correspond to a priori expected performances and are associated with WMC, it is reasonable to assume that the reported strategies actually reflect strategies that are being used. In the present study it is expected that:

- repetition should be the most common strategy reported (Turley-Ames and Whitfield 2003, 446-468), also see Swanson, Kehler and Jerman (2010, 24–47);
- there will be an association between the strategy complexity and performance, hence children reporting more complex strategies will perform better than those reporting less complex strategies (Bjorklund and Zeman 1982, 799–810; Paris et al. 1982, 490–509); and
- there will be an association between strategy complexity and WMC, hence children reporting more complex strategies will score higher on a complex WM task (Beilock and DeCaro 2007, 983–998; Lemaire and Lecacheur 2011, 282–294).

If those three conditions are satisfied, it is assumed that our findings correspond with previous research, thus reflecting valid self-reported strategies and a relation to WMC. With those results as a point of departure, hierarchical regression analyses are used to investigate:

- if self-reported memory strategies are related to performance in immediate and delayed text recall tasks (e.g., Adams and Hitch 1997, 21–38; Schneider et al. 2009, 70–99) when controlling for WMC (e.g., Baddeley 1992, 556–559; Nikolić and Singer 2007, 904–912).

In addition, it is possible that girls use memory strategies more frequently than boys (Braten and Olaussen 1998, 309–327) and gender is therefore included in the analyses. Although the teachers stated that no child included in the study had significant writing, reading ability and/or decoding problems, we measured reading speed (time to read the text) to obtain an indication of how the decoding and comprehension of the text influences the analyses. Reading speed is a fluency measure which provides an indication of the ability to decode and comprehend a text (e.g. Samuels 2012, 3–16).

Methods

Participants

Thirty-three boys and 33 girls participated in the study. All were in the fifth grade (age range from 11 years 4 months to 12 years 2 months) of the Swedish education system and were drawn from three public compulsory schools in northern Swedish municipalities. All children gave their consent to participate, informed consent was obtained from the parents, and no one declined to participate. Of the 66 children, 65 took part in all measurements, and all showed age-adequate writing and reading skills. One child failed to complete the listening span and delayed text recall tasks and those partial results are therefore excluded from the analysis.

Instruments and procedures

The children were given instructions before each task, offered an opportunity to practice, and were encouraged to ask questions to prevent misunderstanding.

Text memory

To measure text memory, the children were asked to read a standardised text that was new to them, with the illustrations removed. The text conformed to a nationally accepted assessment tool of appropriate textbooks for children in fifth grade (Hyden, Schubert and Sviden 2002); it was a 193-word article about a man who worked as a painter in Sweden in the 14th century. The content was assumed to be neutral in relation to the experiences of the children. The children were asked to read the article with the intention of later reproducing the content. When finished, they were instructed to turn the paper over; the reading speed was then noted by one of the authors. Reading the text and the subsequent text recall tasks were conducted in three separate classes with all children present. The memory assessment was based on how well the participants were able to reproduce the content on two occasions. The first occasion was immediately after they had read the text (immediate recall); the second was one week later (delayed recall). On both occasions, they were given instructions to reproduce all details by writing down everything they could remember from the text without worrying about grammar and spelling.

The analysis was based on a system in which the article is divided into units consisting of three to ten words depending on content. Exact reproduction of a unit scored 1 point, a partial reproduction scored 0.5 of a point, and one word or nothing reproduced from the unit scored 0. This method is similar to that used in the "Logical Memory" test in the Wechsler Memory Scale (Wechsler 1987).

Memory strategies

Questions about the memory strategies the participants employed while encoding for later reproduction of the content were asked individually in a separate room after the immediate text recall task. The participants were asked if they had used any specific method to remember the text better. Despite what previous research has shown, it is nevertheless possible that children would be unable to verbalise their actual use of memory strategies for several possible reasons, e.g. shyness or a lack of conceptual understanding; therefore, following Guttentag (1989, 146–170), Gyselinck, Meneghetti, De Beni and Pazzaglia (2009, 12–20) and Turley-Ames and Whitfield (2003, 446–468) they were offered five alternatives to describe their strategies for remembering:

1. *No strategy* – no use of any strategy was reported;
2. *Repetition* – re-reading parts and/or the whole text several times;
3. *Visualisation* – creating images similar to photographs or movies;
4. *Elaboration* – association of the text with prior experience or knowledge; or
5. a *Combination* of two or more specific techniques.

The alternatives were presented in randomised order to prevent systematic bias. The use of *repetition* was defined in the present study as more advanced than using *no strategy* (Guttentag 1989, 146–170) and *visualisation* as more advanced than *repetition* (Gyselinck et al. 2009, 12–20), or at least more cognitively demanding (Turley-Ames and Whitfield 2003, 446). *Elaboration* and a *combination* of memory strategies were considered more advanced than *visualisation* and *repetition,* but were not disentangled in advance. However, no child reported that they used *elaboration* as a memory strategy; consequently, the *combination* of strategies was viewed as being the most advanced strategy employed (Coyle and Bjorklund 1997, 372).

Working memory

Individual WMC was assessed through listening recall tasks (Daneman and Carpenter 1980, 450–460) in which the children were required to process and retain information simultaneously. In the listening span test, the children make judgements about the meaning of a series of sentences while trying to remember the last word of each sentence for subsequent recall. It requires them to both store and process increasing amounts of information and includes different levels that are characterised by the number of sentences in each set. In terms of vocabulary and syntactic complexity, the sentences are held constant at the different levels and it is only the number of words to be recalled that increases as the level rises. The numbers of correct words in the response were added together for the score. Complex span tasks have been shown to have good reliability and validity when measuring individuals' WMC (Conway et al. 2005, 769–786). The listening span task was administered individually in a separate room during regular school time.

Statistical analyses

All analyses were conducted with SPSS 18. Performances in the listening span test (WMC), reading speed, and text recall tasks were screened for outliers. Two outliers were found in the results for the immediate and delayed recall tasks, and two in the results for reading speed. These were replaced with the series' median values. To evaluate the validity of the self-reported strategies, a frequency analysis of the self-reported strategies (no strategy, repetition, visualisation, combination) was conducted (denoted as *strategies*). A test of the linearity assumption between the independent and dependent variables revealed that strategies deviated significantly from linearity for both immediate text recall ($p = 0.026$) and delayed text recall ($p = 0.03$). The analysis of skewness and kurtosis revealed that strategies and reading speed were moderately skewed (0.70 and 0.90, respectively) and that kurtosis for reading speed was outside three standard errors.[1] Considering the skewness, kurtosis and deviation analyses, we log10 transformed reading speed and strategies. After this transformation, the analyses of the deviations from linearity were non-significant (all $p > 0.5$) for both reading span and strategies with immediate and delayed text recall, respectively. Skewness was within $-½$ to $+½$ and kurtosis within three standard error deviations for reading speed and strategies, respectively. To investigate the associations between the strategies, WMC, reading speed, gender, immediate recall and delayed recall, Spearman rank correlation analyses were conducted. To disentangle the distinction between reporting using some kind of memory strategy (strategy) and reporting no use of strategies (no strategy), and to increase the power of the analyses, the self-reported strategies *combination*, *visualisation* and *repetition* were amalgamated into one (denoted as *strategy*). Two hierarchical regression analyses were used to evaluate the main effects of strategy (strategy, no strategy), a categorical variable, while controlling for WMC and reading speed as continuous variables, and gender as a categorical variable. The regression analyses were conducted for each dependent measurement; that is, immediate and delayed recall. To control for WMC, gender, and reading speed before evaluating the contribution of strategy, WMC and gender were entered in the first step, reading speed in the second step and self-reported memory strategy in the third step. Immediate and delayed recall were entered as dependent variables. For each step, the increment in the variance is reported together with the standardised beta-value, *F*-change, *t*-values and squared semi-partial correlations, sr^2. The squared semipartial correlation indicates the amount of variance that was uniquely accounted for by a specific variable. Statistically, median split and percentile group analyses can be problematic (MacCallum et al. 2002, 19); however, a dichotomisation of WMC was performed and conceptualisation of the results was obtained through two mixed model ANOVAs.

Results

We first conducted frequency analyses to evaluate the distribution of self-reported strategies. Table 1 shows the frequency of the strategies along with the mean values and standard deviations of the text memory scores. A chi square analysis confirms that repetition was the most common strategy reported ($n = 34$) and that very few children reported using visualisation as a strategy, $\chi^2(3, N = 65) = 27.93$, $p < 0.0001$.

Table 1. Children’s self-reported strategies at immediate and delayed text recall

	Immediate recall		Delayed recall
Strategy	*n*	M (SD)	M (SD)
No strategy	15	7.53 (4.64)	4.06 (4.06)
Repetition	34	12.21 (5.04)	8.56 (4.76)
Visualisation	5	9.20 (5.03)	6.20 (3.61)
Combination	12	14.92 (5.09)	12.55 (3.76)

Note: The table shows mean values and standard deviations for immediate and delayed text recall. *n* denotes the number of participants and their self-reported strategies.

To investigate the associations between strategies (no strategy, repetition, visualisation, combination), WMC, gender, reading speed, and immediate and delayed recall, Spearman rank correlation analyses were conducted (Table 2). WMC was found to be significantly correlated with strategies, immediate and delayed recall. As expected, children reporting more complex strategies had a higher WMC. Strategies were found to be positively correlated with both immediate and delayed recall. Also as expected, more complex memory strategies were correlated with better performances in both immediate and delayed text recall.

Table 2. Spearman rank correlations table for WMC, gender, reading speed, strategies (No strategy, repetition, visualisation, combination of strategies), and immediate and delayed recall

Variables	1	2	3	4	5	6
1. WMC		0.17	−0.16	0.39**	0.55**	0.54**
2. Gender			−0.25	0.40*	0.32*	0.32*
3. Reading speed				−0.04	−0.07	−0.02
4. Strategies					0.41*	0.50**
5. Immediate recall						0.78**
6. Delayed recall						

Note: ** $p < .01$, * $p < .05$

Two hierarchical regression analyses were conducted to evaluate the contribution of strategy (strategy no, strategy), WMC, gender, and reading speed. As shown in Tables 3 (a & b), WMC and gender were found to be significant predictors in step 1 for both immediate and delayed recall, explaining 37% and 39% of the variance, respectively. In step 2, WMC and gender remained significant in both immediate and delayed recall; however, entering reading speed did not incrementally contribute to either of the analyses. In the final step, WMC remained significant. The entry of strategy contributed significantly in both immediate and delayed text recall (although this was only marginally significant in immediate recall). The explained variance grew incrementally for both immediate and delayed recall, explaining 41% and 43%, respectively. The regression analyses confirm the prediction that WMC is a significant predictor of both immediate and delayed text recall and that strategy, together with WMC, are a significant predictor of performances above the influence of reading speed and gender. Gender as a significant predictor disappears in both immediate and delayed recall upon entering self-reported strategies in the analyses. The non-significant effect of reading speed shows that the amount of time spent reading the text did not influence performance in either immediate or delayed recall. In the two regression analyses, SPSS reported tolerance values as measures of multicollinearity; i.e. a control measure of whether predictor variables are highly linearly related. The presence of multicollinearity makes it difficult to assess the individual importance of a single predictor. The tolerance values were in the range 0.70–0.97 and were therefore considered acceptable. Hence, a rule of thumb is that a value of less than 0.1 may indicate the presence of large multicollinearity (Lin 2008, 417–426).

Table 3a. Hierarchical regression analysis predicting immediate text recall

Step	R	R^2	F change	β	sr^2	t-value
Step 1	.61	.37	18.33***			
WMC				0.52	0.26	5.08***
Gender				0.24	0.05	2.38*
Step 2	61	.38	0.80			
WMC				0.53	0.27	5.14***
Gender				0.26	0.06	2.49*
Reading speed				0.09	0.00	0.89
Step 3	.63	.41	3.34			
WMC				0.47	0.19	4.45***
Gender				0.17	0.02	1.47
Reading speed				0.03	0.00	0.32
Strategy				0.22	0.03	1.82^{+}

Note: ***$p < .001$, *$p < .05$, $^{+}p < .10$

Table 3b. Hierarchical regression analysis predicting delayed text recall

Step	R	R^2	F change	β	sr^2	t value
Step 1	.62	.39	19.90***			
WMC				0.53	0.27	5.27***
Gender				0.25	0.06	2.51*
Step 2	63	.39	0.43			
WMC				0.54	0.28	5.29***
Gender				0.26	0.06	2.59*
Reading speed				0.07	0.00	0.66
Step 3	.66	.43	4.10*			
WMC				0.48	0.20	4.57***
Gender				0.16	0.02	1.47
Reading speed				−0.05	0.00	−0.47
Strategy				0.24	0.04	2.03*

Note: ***$p < .001$, *$p < .05$

The significant effects of WMC and strategy on immediate and delayed text recall performances are illustrated in Figure 1 (a & b). For comparison purposes, WMC was divided along a median split into two WMC groups, i.e. participants scoring below the median value in the listening span task were placed in the low WMC group and participants scoring above the median value in the high WMC group (Figure 1a). The strategy variable is displayed as analysed; participants not reporting having any strategies were placed in the no-strategy group and participants reporting having some sort of strategy were placed in the strategy group (Figure 1b). As can be seen in Figure 1a, children in the high WMC span group performed better than those in the low WMC group with both immediate and delayed recall. A mixed model ANOVA with text recall (immediate, delayed) as a within-subject factor and WMC (high, low) as between-subject evaluated the performances and strategy group. The analyses revealed significant within- and between-subject effects, $F(1,63) = 82.51$, $p < 0.0001$, $\eta_p^2 = 0.56$, $F(1,63) = 33.0$, $p < 0.0001$, $\eta_p^2 = 0.87$, respectively. The main effects were not qualified by an interaction between immediate/delayed recall and WMC group, $F(1,63) = 0.44$, $p > 0.5$, $\eta_p^2 = 0.001$. Figure 1b shows that those children who reported they had used memory strategies ($n = 51$) performed in a superior way to children who reported they had not used any memory strategy ($n = 15$), and this difference was present with both immediate and the delayed recall. A mixed model ANOVA with text recall (immediate, delayed) as a within-subject factor and strategy (strategy, no strategy) as between-subject evaluated the performances and strategy group. The analyses revealed significant within- and between-subject effects, $F(1,64) = 62.05$, $p < 0.0001$, $\eta_p^2 = 0.49$, $F(1,64) = 17.28$, $p < 0.0001$, $\eta_p^2 = 0.21$, respectively. The main effects were not qualified by an interaction between immediate/delayed recall and strategy group, $F(1,64) = 0.06$, $p > 0.5$, $\eta_p^2 = 0.00$.

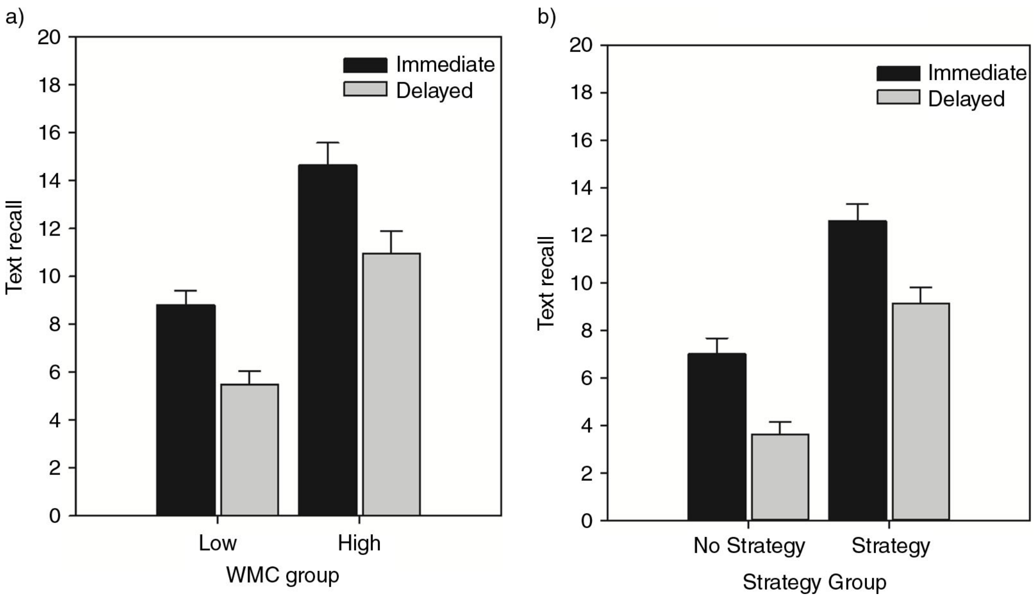

Figure 1. (a & b). Mean values representing immediate recall and delayed recall across low and high WMC group (a) and no strategy and strategy (b). Participants in the high WMC group outperformed participants in the low WMC group in both immediate and delayed recall tasks. Participants who reported strategies outperformed participants who reported no strategy in both immediate and delayed recall tasks. Standard errors are represented by the error bars attached to each column.

Discussion

In the present study, repetition is reported by grade-five children as the most common memory strategy. Children reporting more complex strategies performed better than those reporting less complex strategies, and also scored higher on a complex WM test. This study provides indirect evidence and substantial support for the argument that memory strategies that are self-reported are *de facto* used during the encoding of text. The subsequent hierarchical regression analyses show that children's self-reports of using a memory strategy could be seen as a significant predictor of immediate and delayed text recall, even when controlling for reading speed, WMC and gender.

The frequency analysis reveals that repetition was the strategy most commonly used during encoding for later recall, which corresponds well to previous work by Turley-Ames and Whitfield (2003, 446–468); also see Swanson et al. (2010, 24–47). The significant correlation between strategies (no strategy, repetition, visualisation, combination) and immediate and as well as delayed performances indicates that more complex memory strategies lead to better performances in both immediate and delayed recall compared to less complex memory strategies or no strategies. One exception was visualisation, defined as a more advanced memory strategy than repetition, which should therefore facilitate a stronger performance than repetition. However, as pointed out by Turley-Ames and Whitfield (2003, 466), visualisation is a cognitively demanding strategy; it is therefore possible that children in fifth grade have not yet obtained the required cognitive capacity to use it and do not benefit from using it as a memory strategy. This could reflect a utilisation deficiency (Bjorklund et al. 1997, 411–441); in other words, it may be that using this strategy is too cognitively demanding to facilitate higher recall. These findings show that the usage of more complex memory strategies is more effective for storage in long-term memory when studying text than using less complex strategies (van Blerkom 2009). However, in relation to the present results, it seems important to consider the child's cognitive level if one is introducing more complex strategies such as visualisation.

The significant correlation between WMC and self-reported memory strategies (Table 1) observed in the present study suggests that WMC and the use of memory strategies are related (e.g. Adams and Hitch 1997, 21–38; Bjorklund et al. 1997, 411–441; Pressley and van Meter 1993, 128–165). Although it seems likely that the development of WM precedes the development of strategies, the results in this study do not provide a causal link between WMC and the ability to acquire memory strategies. It therefore cannot be ruled out that strategy use and WMC are at least partly bidirectional (Best 1993, 324–336).

This study demonstrates that children are able to reflect with accuracy on their own thinking also see (Lai 2011) and, in addition, that their self-reported strategies are valid. With these findings as a point of departure, the hierarchical regression evaluated whether having a strategy is predictive of immediate and long-term text recall even when controlling for WMC, gender and reading speed. The results showed that reporting a strategy can be viewed as a reliable predictor of children's performances above the influence of all three variables. However, it is important to point out that the strongest predictor was in fact WMC, which also remained significant across all three steps. Why does WMC have this effect? A possible explanation is that individual differences in WM are related to the amount of WMC available (Cantor and Engle 1993, 1101–1114). In vision, the information needs to enter WM before it can be moved into long-term memory. This is evidenced by the fact that the speed with which information is moved into long-term memory is determined by the amount of information that can be fit, in each step, into visual WM (Nikolić and Singer 2007, 904–912). In other words, the larger the capacity of WM for certain stimuli, the faster these materials will be learned and the more likely they will be remembered. This result fits well with the many other studies showing that WMC and the executive functions are indeed related to performances (e.g. Alloway and Alloway 2010, 20–29; Alloway et al. 2009, 606–621; Andersson and Lyxell 2007, 197–228). Another possible explanation is that children with higher WM spans are better able to inhibit irrelevant information (e.g. Rosen and Engle 1997, 211–227).

In the present study, 22% of the children reported they did not use a particular memory strategy. Why? One possible explanation of this absence is that they either have no knowledge of memory strategies or do not know how to utilise them. An alternative suggestion is that, although they do use strategies to help them remember, they do not report them; however, as inferred from previous research (e.g. Bjorklund and Zeman 1982, 799–810) this is an unlikely scenario. Instead, the significant positive correlation between WMC and strategies (no strategy, repetition, visualisation, combination) together with the results from the regression analysis, the significant contribution of WMC as a single predictor in the immediate and delayed recall indicates that WMC is the key component that explains the lack of memory strategies. This is supported by the argument of Adams and Hitch (1997, 21–38) who concluded that the ability to develop memory strategies is related to WMC. In the present study, it is possible that for some children the combination of having a low WMC and a highly demanding cognitive task leads to a cognitive overload, which in turn leaves no cognitive resources available to implement memory strategies (Joyner and Kurtz-Costes 1997, 275–300). It is even possible that the present study underestimated the effect of WMC on text recall. It was shown in a study by Lépine, Parrouillet and Camos (2005, 165–170) that a computer-paced WM task (where a computer controls the pace at which the stimulus is presented) consisting of reading successive letters, in comparison to self-paced WM tasks (where the pace at which the stimulus is presented is controlled by the individual) was more predictive of academic performances such as literacy. Hence, performing tasks when there is a time constraint limits the time available to utilise strategies and, with less time, the participants must rely to a larger extent on their WMC. In the present study, there were no time constraints, giving the children time to utilise memory strategies that in turn perhaps suppressed the potential effect of the WM load and facilitated a stronger performance in the text recall tasks. A time constraint during encoding may have reduced the possibility of employing strategies and increased the effect of WMC. However, the regression analyses showed that reading speed had no effect, indicating that the time children spent during encoding did not affect their performances.

There are some limitations to the present study. Retrieval without writing the answers down could have generated a somewhat different result. A basic assumption was that the children were aware of all their strategies, or would become aware of them when presented with alternatives. Yet it is possible that more automatic strategies are employed unconsciously or that they are unable to verbalise available strategies. Although they were asked and encouraged to tell which strategies they were using, it is thus possible that strategies are missed. There was no control over the children's activities in the week between the immediate and delayed tests. Controlling for general intelligence and also the inclusion of other WM tasks may have increased the validity of the results. However, complex WM tasks such as the listening span test have been found to correlate reasonably well with intelligence and reading comprehension (e.g. Daneman and Carpenter 1980, 450–466; Schweizer and Moosbrugger 2004, 329–347). In addition, when asked, the teachers stated that the individual child's regular school performance was within the normal distribution.

In summary, our study extends previous findings showing that memory strategies are crucial for doing well in memory tasks and that WMC is the key component (Adams and Hitch 1997, 21–38). In our study, there were no direct and independent measurements of the extent to which memory strategies were actually used. Naturally, there are problems with reliance on self-reporting such as interviews and a think-aloud protocol; strategies are cognitive and covert in their nature and cannot be easily measured (Joyner and Kurtz-Costes 1997, 275–300). Direct observations are, of course, an alternative option; however, if not video-recorded (e.g. Beilock and DeCaro 2007, 987), the observed behaviour is a transient event which requires on-line rating and the use of multiple raters to be considered reliable. Another option is to manipulate the strategy information that is given to the children and measure the changes in performance (Turley-Ames and Whitfield 2003, 446–468). An alternative way to investigate and validate children's use of strategies is, like in the present study, to relate self-reported strategies with the expected pattern of performance and with more objective measures such as standardised measures of WMC. Taking the present results together with previous research, in which most assessments utilised interviews and questionnaires (Joyner and Kurtz-Costes 1997, 275–300), we are provided with substantial evidence that the self-reporting of memory strategies is indicative of the actual use of such strategies. It thus seems plausible to argue that if children in fifth grade are unable to report that they use memory strategies, they are either unaware of how to use them, have poor working memory, or both. In any case, this should be a clear warning signal to further investigate the individual child's learning strategies. If a pupil is identified as having a low WMC it is crucial to further investigate whether they also lack appropriate memory strategies. Hence, since studies have shown that individuals with a low WMC can reduce their load on WM by using rehearsal as a strategy (McNamara and Scott 2001, 10–17; Rosen and Engle 1997, 211–227; Turley-Ames and Whitfield 2003, 446–468), we therefore argue that children with a low WMC and/or no strategies in their cognitive repertoire will benefit from special education that focuses on memory strategies. Nevertheless, it is also imperative for teachers to use numerous strategies to help students recall information. By combining a variety of teaching techniques, teachers can ensure that each student, regardless of their learning style, will recall information effectively.

In addition, children who perform poorly in school should be considered as potentially lacking memory strategies and having a low WMC (e.g. Alloway and Alloway 2010, 20–29; Wang and Gathercole 2013, 188–197). Increasing teacher awareness of the importance of WMC for teaching and learning strategies is crucial (Gathercole et al. 2008, 214–223). If children are constrained by the limits of WM (Brünken et al. 2002, 109–119), they are also likely to lack constructive memory strategies (Adams and Hitch 1997, 21–38; Schneider et al. 2009, 70–99), which places these learners in a vulnerable learning situation with a greater risk of lagging further behind (Gathercole et al. 2008, 214–223). Educationally, it is therefore important to teach pupils to compensate for a low WMC by employing adequate memory strategies (Dehn 2011).

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Note

1 Skewness (SE) for WMC, immediate text recall, delayed text recall, strategies (no strategy, repetition, visualization & combination of strategies) & reading speed were −0.74(0.30), 0.33(0.29), 0.48(0.29), 0.70(0.29), 0.98(0.28). Kurtosis (SE) were −0.66(0.58), −0.69(0.58), −0.84(0.52), −0.49(0.58), 1.9(0.45), respectively.

References

Adams, John & Hitch, Graham. (1997). Working memory and children's mental addition. *Journal of Experimental Child Psychology*, 67(1): 21–38. doi: 10.1006/jecp.1997.2397.

Alloway, T. P. & Alloway, R. G. (2010). Investigating the predictive roles of working memory and IQ in academic attainment. *Journal of Experimental Child Psychology*, 106(1): 20–29. doi: S0022-0965(09)00202-1 [pii]10.1016/j.jecp.2009.11.003.

Alloway, T. P., Gathercole, S. E., Kirkwood, H. & Elliott, J. (2009). The cognitive and behavioral characteristics of children with low working memory. *Child Development*, 80(2): 606–621. doi: CDEV1282 [pii]10.1111/j.1467-8624.2009.01282.x.

Andersson, U. & Lyxell, B. (2007). Working memory deficit in children with mathematical difficulties: a general or specific deficit? *Journal of Experimental Child Psychology*, 96(3): 197–228. doi: 10.1016/j.jecp.2006.10.001.

Baddeley, A. (1992). Working memory. *Science*, 255(5044): 556–559. doi: 10.1126/science.1736359.

Baddeley, A. (2000). The episodic buffer: a new component of working memory? *Trends in Cognitive Sciences*, 4(11), 417–423.

Baddeley, Alan. (2010). Working memory. *Current Biology*, 20(4): 136–140. doi: http://dx.doi.org/10.1016/j.cub.2009.12.014.

Beilock, Sian & deCaro, Marci. (2007). From poor performance to success under stress: working memory, strategy selection, and mathematical problem solving under pressure. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 33(6): 983–998. doi: 10.1037/0278-7393.33.6.983.

Best, D. L. (1993). Inducing children to generate mnemonic organizational strategies: an examination of long-term retention and materials. *Developmental Psychology*, 29(2): 324–336. doi: 10.1037/0012-1649.29.2.324.

Bjorklund, D. F. & Zeman, B. R. (1982). Children's organization and metamemory awareness in their recall of familiar information. *Child Development*, 53(3): 799–810. http://www.jstor.org/stable/1129394.

Bjorklund, D. F., Miller, P. H., Coyle, T. R. & Slawinski, J. L. (1997). Instructing children to use memory strategies: evidence of utilization deficiencies in memory training studies. *Developmental Review*, 17(4): 411–441: doi: 10.1006/drev.1997.0440.

Braten, Ivar & Olaussen, Bodil. (1998). The learning and study strategies of Norwegian first-year college students. *Learning and Individual Differences*, 10(4): 309–327. doi: 10.1016/s1041-6080(99)80125-3.

Broadway, James & Engle, Randall. (2011). Individual differences in working memory capacity and temporal discrimination. *PLoS ONE*, 6(10): e25422. doi: 10.1371/journal.pone.0025422.

Brünken, Roland, Steinbacher, Susan, Plass, Jan & Leutner, Detlev. (2002). Assessment of cognitive load in multimedia learning using dual-task methodology. *Experimental Psychology*, 49(2): 109–119. doi: 10.1027//1618-3169.49.2.109.

Cantor, J. & Engle, R. (1993). Working-memory capacity as long-term memory activation: an individual-differences approach. *Journal of Experimental Psychology Learning, Memory, and Cognition*, 19(5): 1101–1114. doi: 10.1037/0278-7393.19.5.1101.

Carney, R. N. (2011). Memory strategies. In *Encyclopedia of Child Behavior and Development*, Sam Goldstein & Jack A. Naglieri (eds.), 937–938. New York: Springer.

Carr, Martha, Kurtz, Beth, Schneider, Wolfgang, Turner, Lisa & Borkowski, John G. (1989). Strategy acquisition and transfer among American and German children: environmental influences on metacognitive development. *Developmental Psychology*, 25(5): 765–771. doi: 10.1037/0012-1649.25.5.765.

Conway, Andrew, Kane, Michael, Bunting, Michael, Hambrick, Zach, Wilhelm, Oliver & Engle, Randall. (2005). Working memory span tasks: a methodological review and user's guide. *Psychonomic Bulletin and Review*, 12(5): 769–786. doi: 10.3758/BF03196772.

Coyle, T. R. & Bjorklund, D. F. (1997). Age differences in, and consequences of, multiple-and variable-strategy use on a multitrial sort-recall task. *Developmental Psychology*, 33(2), 372–380. doi: 10.1037/0012-1649.33.2.372.

Cross, David R. & Paris, Scott. (1988). Developmental and instructional analyses of children's metacognition and reading comprehension. *Journal of Educational Psychology*, 80(2): 131–142. doi: 10.1037/0022-0663.80.2.131.

Daneman, Meredyth & Carpenter, Patricia. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior*, 19(4): 450–466. doi: http://dx.doi.org/10.1016/S0022-5371(80)90312-6.

Dehn, Milton. (2008). *Working memory and academic learning: assessment and intervention*. John Wiley and Sons.

Gathercole, S. & Pickering S. (2001). Working memory deficits in children with special educational needs. *British Journal of Special Education*, 28(2): 89–97. doi: 10.1111/1467-8527.00225.

Gathercole, S. E., Pickering, S., Ambridge, B. & Wearing, H. (2004). The structure of working memory from 4 to 15 years of age. *Developmental Psychology*, 40(2): 177–189. doi: 10.1037/0012-1649.40.2.177.

Gathercole, Susan, Alloway, Tracy, Kirkwood, Hannah, Elliott, Julian, Holmes, Joni & Hilton, Kerry. (2008). Attentional and executive function behaviours in children with poor working memory. *Learning and Individual Differences*, 18(2): 214–223. doi: 10.1016/j.lindif.2007.10.003.

Gathercole, Susan & Pickering, Susan. (2000a). Assessment of working memory in six- and seven-year-old children. *Journal of Educational Psychology*, 92(2): 377–390. doi: 10.1037//0022-0663.92.2.377.

Gathercole, Susan & Pickering, Susan. (2000b). Working memory deficits in children with low achievements in the national curriculum at 7 years of age. *British Journal of Educational Psychology*, 70(2): 177–194. doi: 10.1348/000709900158047.

Guttentag, R. E. (1989). Age differences in dual-task performance: procedures, assumptions, and results. *Developmental Review*, 9(2): 146–170. doi: 10.1016/0273-2297(89)90027-0.

Gyselinck, Valérie, Meneghetti, Chiara, De Beni, Rossana & Pazzaglia, Francesca. (2009). The role of working memory in spatial text processing: what benefit of imagery strategy and visuospatial abilities? *Learning and Individual Differences*, 19(1): 12–20. doi: 10.1016/j.lindif.2008.08.002.

Hasselhorn, M. (1992). Task dependency and the role of category typicality and metamemory in the development of an organizational strategy. *Child Development*, 63(1): 202–214. doi: 10.1111/1467-8624.ep9203091737.

Henry, Lucy A. & Norman, Tricia. (1996). The relationships between memory performance, use of simple memory strategies and metamemory in young children. *International Journal of Behavioral Development*, 19(1): 177–199. doi: 10.1177/016502549601900113.

Hitch, Graham, Towse, John & Hutton, Una. (2001). What limits children's working memory span? Theoretical accounts and applications for scholastic development. *Journal of Experimental Psychology: General*, 130(2): 184–198. doi: 10.1037/0096-3445.130.2.184.

Hydén, Görel, Schubert, Magdalena & Svidén, Cecilia. (2012). *Läsförståelse, D.* 2. uppl. Lund: Studentlitteratur

Joyner, M. H. & Kurtz-Costes, B. (1997). Metamemory development. In *The Development of Memory in Childhood*, Nelson Cowan (ed.), 275–300. East Sussex, UK: Psychology Press.

Justice, Elaine. (1985). Categorization as a preferred memory strategy: developmental changes during elementary school. *Developmental Psychology*, 21(6): 1105–1110. doi: 10.1037/0012-1649.21.6.1105.

Kuhn, Deanna & Dean, David Jr. (2004). Metacognition: a bridge between cognitive psychology and educational practice. *Theory Into Practice*, 43(4): 268–273. doi: 10.1207/s15430421tip4304_4.

Lai, E. R. (2011). Metacognition, a literature review. Research report. http://www.pearsonassessments.com/hai/images/tmrs/Metacognition_Literature_Review_Final.pdf (Accessed 2011-10-12)

Lemaire, Patrick & Lecacheur, Mireille. (2011). Age-related changes in children's executive functions and strategy selection: a study in computational estimation. *Cognitive Development*, 26(3): 282–294. doi: 10.1016/j.cogdev.2011.01.002.

Lépine, R., Parrouillet, P. & Camos, V. (2005). What makes working memory spans so predictive of high-level cognition? *Psychonomic Bulletin and Review*, 12(1): 165–170. doi: 10.3758/BF03196363.

Lin, Feng-Jenq. (2008). Solving multicollinearity in the process of fitting regression model using the nested estimate procedure. *Quality and Quantity*, 42(3): 417–426. doi: 10.1007/s11135-006-9055-1.

MacCallum, Robert, Zhang, Shaobo, Preacher, Kristopher & Rucker, Derek. (2002). On the practice of dichotomization of quantitative variables. *Psychological Methods*, 7(1): 19–40. doi: 10.1037/1082-989X.7.1.19.

McMurray, Sharon. (2011). Improving working memory: supporting students' learning – by Tracey Packiam Alloway. *British Journal of Special Education*, 38(3): 155. doi: 10.1111/j.1467-8578.2011.00511_2.x.

McNamara, Danielle & Scott, Jennifer. (2001). Working memory capacity and strategy use. *Memory and Cognition*, 29(1): 10–17. doi: 10.3758/bf03195736.

Moynahan, E. D. (1978). Assessment and selection of paired associate strategies: a developmental study. *Journal of Experimental Child Psychology*, 26(2): 257–266. doi: 10.1016/0022-0965(78)90005-x.

Nikolić, Danko & Singer, Wolf. (2007). Creation of visual long-term memory. *Perception and Psychophysics*, 69(6): 904–912. doi: 10.3758/BF03193927.

Paris, Scott, Newman, Richard & McVey, Kelly. (1982). Learning the functional significance of mnemonic actions: a microgenetic study of strategy acquisition. *Journal of Experimental Child Psychology*, 34(3): 490–509. doi: http://dx.doi.org/10.1016/0022-0965(82)90073-X.

Pressley, M. & Van Meter, P. (1993). Memory strategies: natural development and use following instruction. *Emerging Themes in Cognitive Development*, 2, 128–165.

Rosen, V. M. & Engle, R. W. (1997). The role of working memory capacity in retrieval. *Journal of Experimental Psychology: General*, 126(3): 211–227. doi: 10.1037/0096-3445.126.3.211.

Samuels, Jay. (2012). Reading fluency: its past present and future. In *Fluency Instruction: Research-Based Best Practices*, Timothy Rasinski, Camille Blachowicz & Kristin Lems (eds.), 3–16. New York: Guilford Press.

Schlagmüller, Matthias & Schneider, Wolfgang. (2002). The development of organizational strategies in children: evidence from a microgenetic longitudinal study. *Journal of Experimental Child Psychology*, 81(3): 298–319. http://dx.doi.org/10.1006/jecp.2002.2655.

Schleepen, Tamara & Jonkman, Lisa. (2012). Children's use of semantic organizational strategies is mediated by working memory capacity. *Cognitive Development*, 27(3): 255–269. doi: http://dx.doi.org/10.1016/j.cogdev.2012.03.003.

Schneider, W., Kron, V., Hünnerkopf, M. & Krajewski, K. (2004). The development of young children's memory strategies: first findings from the Würzburg longitudinal memory study.

Journal of Experimental Child Psychology, 88(2): 193–209. http://dx.doi.org/10.1016/j.jecp.2004.02.004.

Schneider, Wolfgang. (2008). The development of metacognitive knowledge in children and adolescents: major trends and implications for education. *Mind, Brain, and Education*, 2(3): 114–121. doi: 10.1111/j.1751-228X.2008.00041.x.

Schneider, Wolfgang, Kron-Sperl, Veronika & Hünnerkopf, Michael. (2009). The development of young children's memory strategies: evidence from the Würzburg Longitudinal Memory Study. *European Journal of Developmental Psychology*, 6(1): 70–99. doi: 10.1080/17405620701336802.

Schraw, Gregory & Moshman, David. (1995). Metacognitive theories. *Educational Psychology Review*, 7(4): 351–371. doi: 10.1007/BF02212307.

Schweizer, K. & Moosbrugger, H. (2004). Attention and working memory as predictors of intelligence. *Intelligence*, 32(4): 329–347. doi: 10.1016/j.intell.2004.06.006.

Sencibaugh, Joseph (2007). Meta-analysis of reading comprehension interventions for students with learning disabilities: strategies and implications. *Reading Improvement*, 44(1), 6–22.

Swanson, H. L., Kehler, P. & Jerman, O. (2010). Working memory, strategy knowledge, and strategy instruction in children with reading disabilities. *Journal of Learning Disabilities*, 43(1): 24–47. doi: 10.1177/0022219409338743.

Turley-Ames, Kandi & Whitfield, Michelle. (2003). Strategy training and working memory task performance. *Journal of Memory and Language*, 49(4): 446–468. doi: http://dx.doi.org/10.1016/S0749-596X(03)00095-0.

Unsworth, Nas & Engle, Randall. (2007). The nature of individual differences in working memory capacity: active maintenance in primary memory and controlled search from secondary memory. *Psychological Review*, 114(1): 104–132. doi: 10.1037/0033-295X.114.1.104.

Van Blerkom, Malcolm. (2009). *Measurement and statistics for teachers*. New York, Routledge.

Wang, Shinmin & Gathercole, Susan. (2013). Working memory deficits in children with reading difficulties: memory span and dual task coordination. *Journal of Experimental Child Psychology*, 115(1): 188–197. doi: http://dx.doi.org/10.1016/j.jecp.2012.11.015.

Wechsler, D. (1987). *Manual: Wechsler Memory Scale - revised*. San Antonio: Psychological Corporation.

Whitebread, David, Coltman, Penny, Pino Pasternak, Deborah, Sangster Claire, Grau, Valeska, Bingham, Sue, Almeqdad, Qais & Demetriou, Demetra. (2009). The development of two observational tools for assessing metacognition and self-regulated learning in young children. *Metacognition and Learning*, 4(1): 63–85. doi: 10.1007/s11409-008-9033-1.