Working memory and Primary National Strategy strands for mathematics

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What is working memory?

Working Memory (WM) (Baddeley & Hitch, 1974)

► ***Complex Working Memory (CWM)***

Central executive

Domain general resource responsible for co-ordination of two domain specific slave systems and attention and inhibition, task shifting, strategy adoption

► ***Verbal Short-Term Memory (VSTM)***

Phonological Loop

Domain specific, limited capacity slave system responsible for short-term storage and processing of verbally encoded material from spoken or written sources.

► ***Non-Verbal Short-Term Memory (NVSTM)***

Visuospatial Sketchpad

Domain specific limited capacity slave system responsible for short-term storage and processing of non-verbal information, including form and colour, spatial orientation, distance and movement.

Why is it important?

The WM model has been cited in the development of mathematical abilities of children at range of ages (Holmes & Adams, 2006; Jarvis & Gathercole, 2003). Phonological and visuospatial WM have been implicated in mathematical ability and explicit types of arithmetical operation, e.g. mental arithmetic (Jarvis & Gathercole, 2003), retaining problem information (Adams & Hitch, 1998), addition (Lemaire, Abdi, & Fayol, 1996) and multiplication (Seitz & Schumann-Hengsteler, 2000). Central executive WM is also thought to play an important role in children's mathematical proficiencies (Bull & Scerif, 2001; Pennington & Willis, 2004, 2005).

Given the potentially important role that WM is reported to play in mathematical attainment it is advantageous to explore relationships between WM and the key strands taught under the Primary National Strategy (PNS). This study was designed to assess the contribution of working memory to four core PNS strands.

What did we do?

70 children from 2 primary schools were tested on WM measures during their Reception year at school and then two years later they were tested on their mathematics abilities to assess any predictive value of WM measures and curriculum based maths.

► **Time 1 : WM measures :** (Mean age 61mths, SD 3.79)
- ► Verbal short-term memory (*Word List and Non-word Recall*)
- ► Non-verbal short-term memory *(Block Recall and Mazes Memory)*
- ► Complex working memory *(Verbal CWM – Listening Recall and Non-Verbal CWM Odd One Out)*

► **Time 2 : Mathematics measure :** From the Mathematics 5-14 series (NFER-Nelson, 2001) (Mean age 84.6 months, SD 3.83)
- ► *Mathematics 7* from which the PNS strands examined were:
  - ► *Using and applying mathematics*
  - ► *Calculating*
  - ► *Measuring & understanding shape (combined due to data restrictions)*
  - ► *Knowing and using number facts*

What did we find?

Correlational Analysis

Table1. Zero order correlations between WM measures and Mathematics 7, and PNS Strands

		1	2	3	4	5	6	7	8	9	10	11
1	Word List Recall	-										
2	Nonword Recall	.43**	-									
3	Listening Recall	.24*	.26*	-								
4	Odd One Out	.21*	.10	.43**	-							
5	Mazes Memory	.22*	.06	.37**	.35**	-						
6	Block Recall	.04	.10	.08	.33**	.41**	-					
7	Maths 7 Raw Score	.38**	.10	.47**	.53**	.36**	.28**	-				
8	Using and applying maths	.30**	.08	.37**	.45**	.25*	.15	.84**	-			
9	Measuring and understanding shape	.32**	.00	.33**	.31**	.35*	.24*	.79**	.55**	-		
10	Calculating	.43**	.12	.49**	.55**	.42**	.33**	.89**	.70**	.67**	-	
11	Knowing and using number facts	.16	.21*	.34**	.37**	.25*	.31**	.67**	.41**	.45**	.55**	-

**p=.05, **p=.01*

► WM within-construct correlations higher than cross-construct correlations and expected correlations were apparent between cross-construct WM measures

► Strong correlations observed between Mathematics 7 and WM measures taken at age 5, except non-word recall which failed to correlate significantly

► Moderate to strong correlations evident between majority of WM measures and PNS strands, except non-word recall. Non-word recall is considered a more pure measure of VSTM processing as the non-words do not correspond to existing words, meaning that the use of long-term memory representations to support recall of the non-words is prevented

► Strong correlations between PNS strands, with calculating and using and applying mathematics showing the strongest relationship (*r=.69*). All PNS strands were highly correlated with Mathematics 7 showing good internal consistency

Simple Regression Analysis

A simple linear regression analysis revealed that all the WM span scores taken at age 5 predicted **36.5%** of the unique variance ($R^{2\ change}=.36$) in children's total mathematics scores at age 7.

To facilitate a more in depth account of the predictive value of WM on mathematics PNS strands a series of fixed-order unique variance regression analyses (Table 2) were used. This allowed us to assess the overall amount of unique variance in mathematics scores on each PNS strand and also showed which elements of WM were most predictive. For each analysis the corresponding PNS strand was the regressor and the unique contribution of WM (measured as $R^{2\ change}$) was assessed as a predictor.

References

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Hierarchical Regression Analyses

Using and applying maths
R^2 change .29

Model 1 : Measures of WM at age 5 accounted for 29% of the unique variance in scores on *"applying and using mathematics"* at age 7 (ANOVA [f(6, 63)=4.24, p=<.001])

WL ß .38** | **NW ß .13** | **LR ß .18** | **OOO ß .20** | **MM ß -.06** | **BR ß .19**

Measuring and understanding shape
R^2 change .29

Model 2 : WM measures predicted 29% of the unique variance in scores on the PNS strand *"measures, shape and space"* (ANOVA [f(6, 63)=4.16, p=<.001])

WL ß .36** | **NW ß -.22[a]** | **LR ß .22[a]** | **OOO ß .04** | **MM ß -.08** | **BR ß .21[a]**

Calculating
R^2 change .55

Model 3 : WM is accounting for 55% of the unique variance in scores on *"calculating"* (ANOVA [f(6, 63)=12.76, p=<.001])

WL ß.43*** | **NW ß -.22***** | **LR ß .25*** | **OOO ß .26*** | **MM ß .02** | **BR ß .28****

Knowing and using number facts
R^2 change .26

Model 4 : WM is predicting 26% of the variance in the performance on the PNS strand *"knowing and using number facts"* (ANOVA [f(6, 63)=3.70, p=<.01]

WL ß .21[a] | **NWL ß .00** | **LR ß .11** | **OOO ß .14** | **MM ß -.16** | **BR ß .41****

**p=.05, **p=.005, ***p=.001*

What do we conclude?

► WM memory data at age 5 **does** appear to play a significant role in prediction of curriculum based mathematics when maths is measured 2 years following the measurement of WM

► Non-word recall (NWR) at age 5 does not appear to be a significant predictor of PNS strands at age7. This corroborates previous theory suggesting VSTM is not fully functioning until approx 7 years old (Gathercole and Hitch, 1993)

► Evidence suggests that VSTM is in place however. This is apparent by the role that word list (WL) has played in PNS strands. One idea is that WL is a predictor of "using and applying maths" as this strand has largely language based problems

► The importance of Block Recall (BR) in Models 3 &4 could imply that the pupils are representing number and mathematical symbols in an almost exclusive visual manner and relying on visual strategies for answering these questions

► BR not predictive of "measuring and understanding shape". Perhaps due to visual aids on the question sheet (diagrams/shapes etc) providing ongoing visual support, also possible that the VSTM system is developing adequately in this area for pupils to deploy more sophisticated verbal solution strategies

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