University of East Anglia

Working Memory and Learning

Working Memory Training: Is it Strategic?

Darren Dunning

Rationale

- Our previous research has showed that Cogmed working memory training improves performance on non-trained working memory tasks (Low working memory children – Dunning et al. 2013; ADHD children Holmes et al. 2010, etc.)

- To explore how to changes in working memory can be explained cognitively

- One suggestion is that improvements can be explained by the use of strategies

- Introspective reports from children in our own training studies support the notion that, even in absence of direct strategy instruction, training promotes the development of idiosyncratic strategies (Holmes, et al. 2009, 2010)

Rationale

- Strategy use is associated with efficient working memory function (Dunlosky & Kane, 2007; Baddeley, 2000)

- Individuals with high memory spans use strategies more than individuals with low memory spans (Engel, Cantor & Carullo, 1992; Friedman & Miyake, 2004; Turley-Ames & Whitfield, 2003)

- Strategy use also predicts individual differences in span performance, with individuals who use more effective strategies performing better on span tasks (McNamara & Scott, 2001)

Method

- 20 undergraduate students (17 females, Mean age 19,1)
- Reduced training program: 10 days
- 4 working memory tasks taken from the Automated Working Memory Assessment (AWMA) pre- and post-training
  - Digit recall
  - Dot matrix
  - Backward digit recall
  - Mr X
- Free response interview about strategy use was obtained before and after each memory task, pre- and post-training

Pre-Training

Working Memory tasks & Interviews

- Verbal STM – Digit Recall

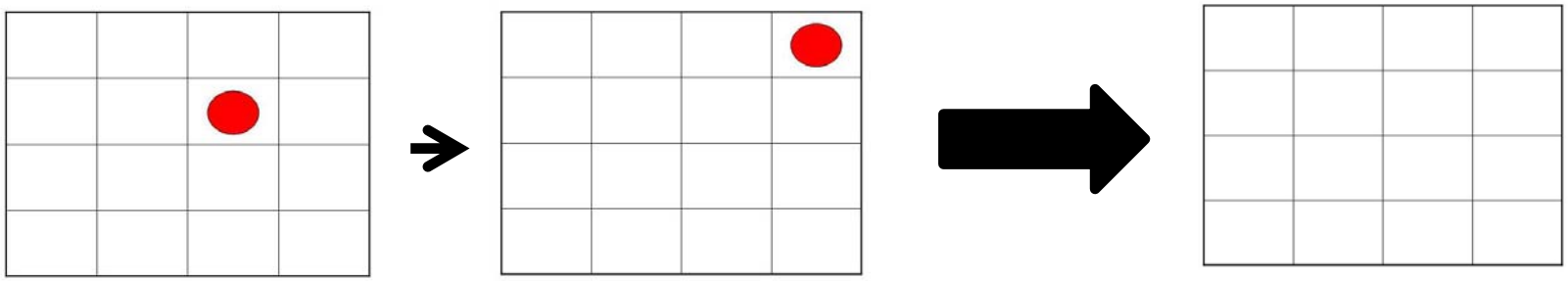
Repeating a list of digits

- Chunking 11
- Rehearsal 8
- Semantic 3
- Using rhythm 2
- Speed 1
- Phonetically 1

Pre-Training

Working Memory tasks & Interviews

- Visuo-spatial STM – Dot matrix



• Made a visual pattern	13
• Chunking	3
• Rehearsed	2
• Verbally recoded	2
• Rhythm	1
• Imagery	1

Pre-Training

Working Memory tasks
& Interviews

- Verbal WM – Backward digit recall

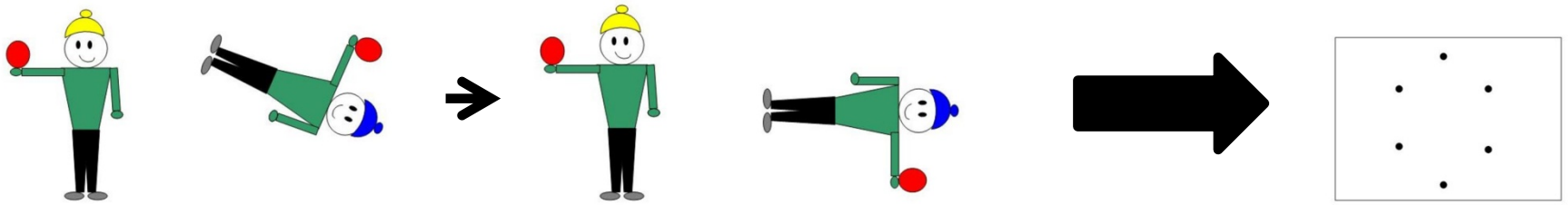
Repeating a list of digits in reverse order

- Rehearsal 13
- Visualised 8
- Chunking 7
- Imagery 1

Pre-Training

Working Memory tasks
& Interviews

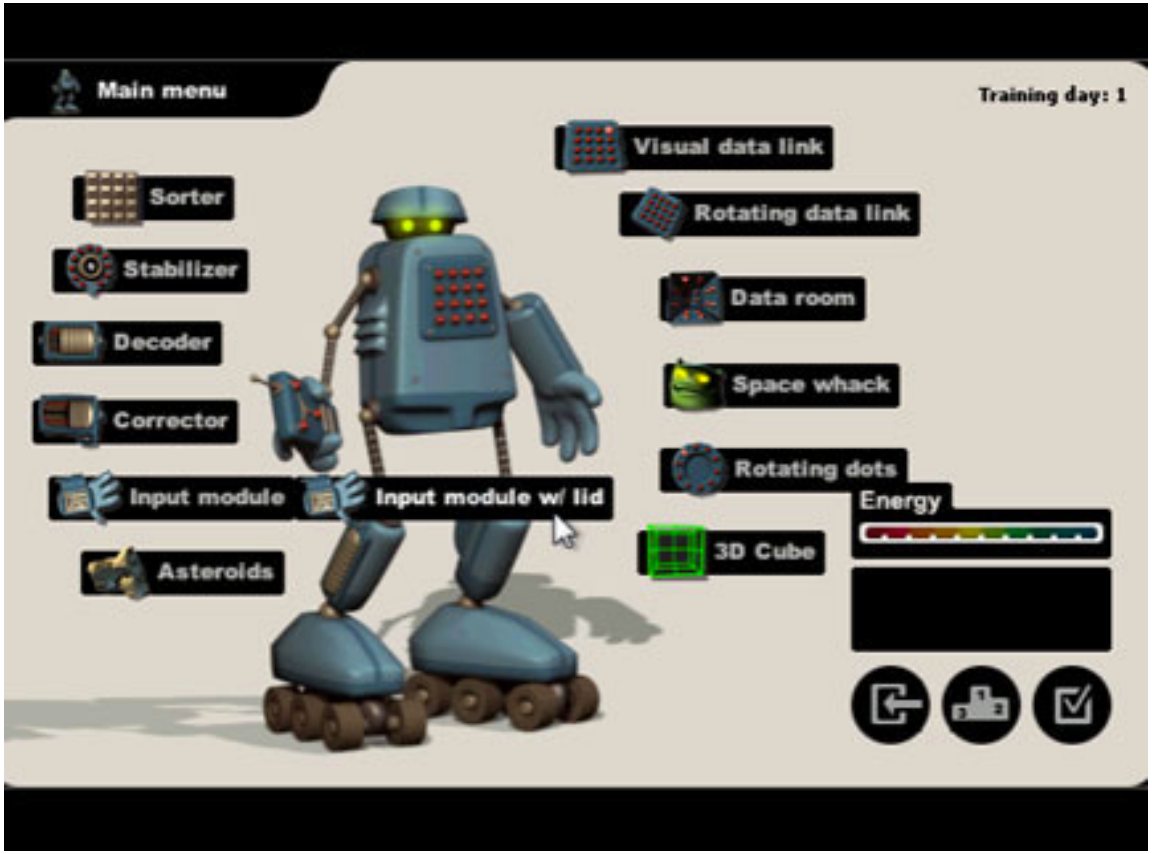
- Visuo-spatial WM – Mr X



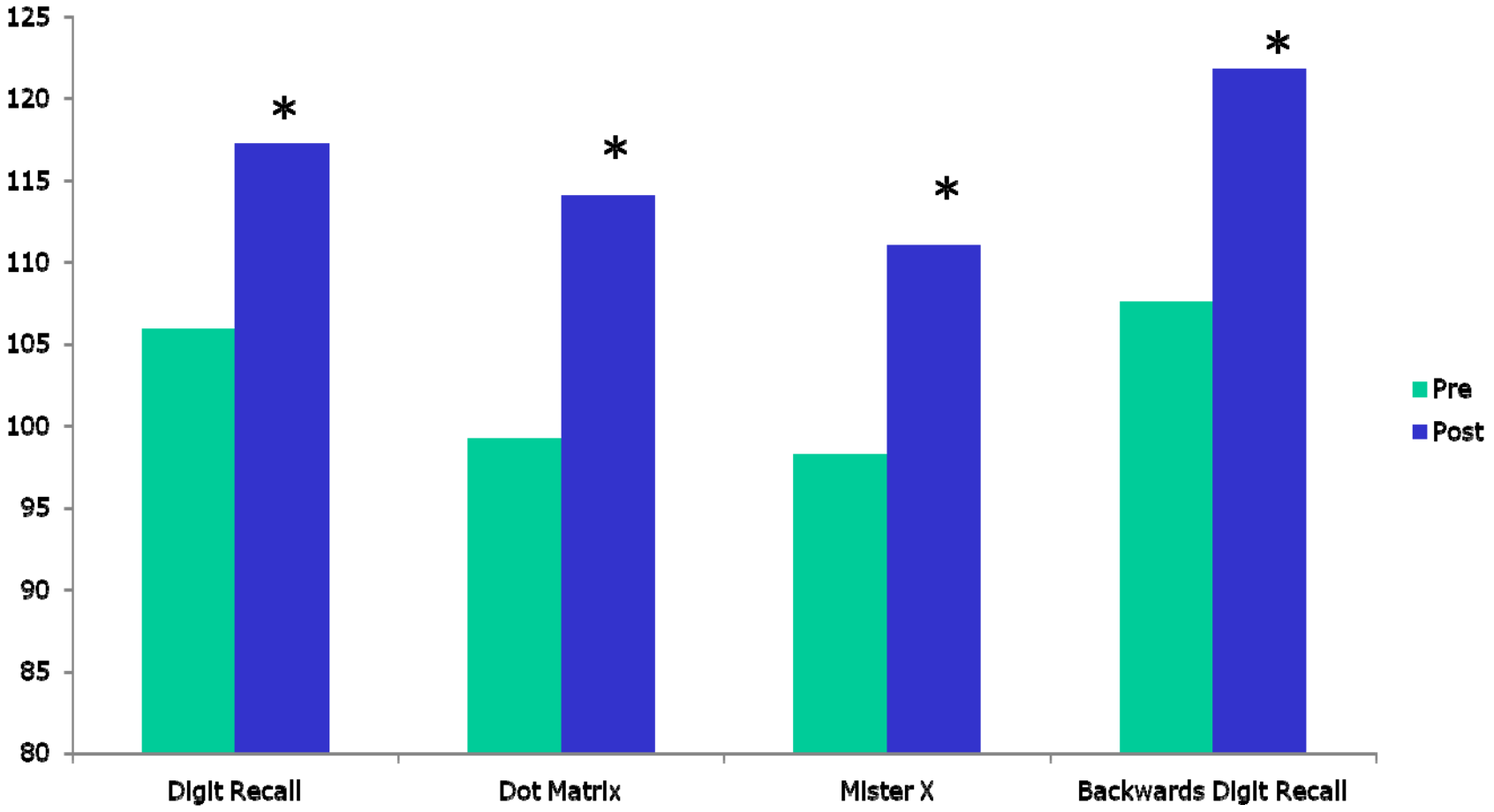
- No strategy used 7
- Visual pattern 5
- Semantic meaning 4
- Rehearsal 1
- Verbally recoding 1
- Inhibited irrelevant info 1
- Imagery 1

Training

- Trained on Cogmed for 10 days at home



Working Memory Results



Strategy change after training

- Verbal STM – Digit Recall

Repeating a list of digits

	pre-	post-training
• Chunking	11	16
• Rehearsal	8	8
• Semantic	3	2
• Using rhythm	2	1
• Speed	1	1
• Phonetically	1	1
• Visual pattern		2

Strategy change after training

- Visuo-spatial STM – Dot matrix

	pre-	post-
• Made a visual pattern	13	11
• Chunking	3	5
• Rehearsal	2	4
• Verbally recoded	2	2
• Rhythm	1	1
• Imagery	1	0

Strategy change after training

- Verbal WM – Backward digit recall

Repeating a list of digits in reverse order

	pre-	post-
• Rehearsal	13	12
• Visualised	8	9
• Chunking	7	10
• Imagery	1	0
• Semantic		2
• Rhythm		1

Strategy change after training

- Visuo-spatial WM – Mr X

	pre-	post-
• No strategy used	7	5
• Visual pattern	5	6
• Semantic meaning	4	4
• Rehearsal	1	0
• Verbally recoding	1	1
• Inhibited irrelevant info	1	0
• Imagery	1	1
• Rhythm		1
• Other		3

Strategy change after training

- *Impact of training on number of strategies used during working memory tasks. Mean number of strategies reported, standard deviation, t scores and Cohen's d effect sizes are shown*

	Pre-training		Post-training			Pre-Post training	
	Mean	*SD*	*Mean*	*SD*	*p*	*t*	*d*
Verbal STM	1.30	0.47	1.55	0.51	0.06	-2.03	-0.51
Visuo-spatial STM -0.28		1.10	0.31	1.20	0.41	0.43	-0.81
Verbal WM	1.45	0.60	1.75	0.55	0.08	-1.37	-0.52
Visuo-spatial WM	0.65	0.49	0.80	0.52	0.19	-1.37	-0.30
Composite score	4.50	0.76	5.30	1.03	<.01	-2.99	-0.88

Summary

- Working memory can be improved in adults who do not have deficits in working memory
- Evidence of strategy use change following training
  - Significant increase in the number of strategies used with more reported at post training than pre-training
  - Change in the type of strategies used post-training (predominantly chunking)

Study 2

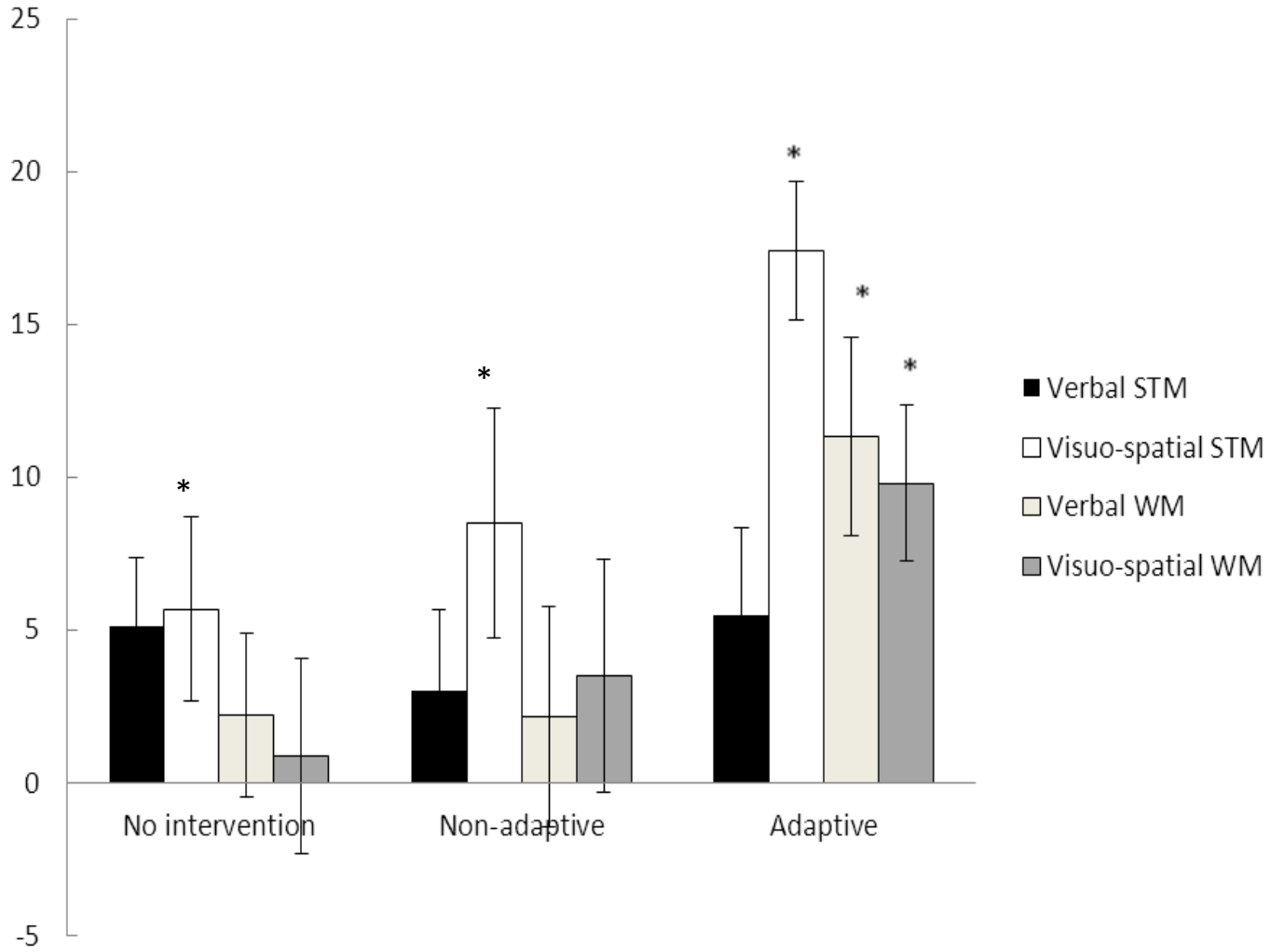
- RCT to replicate the effects
  - Active and passive comparison groups to control for the effects of training

- 45 undergraduates, n=15 per condition
  - Adaptive training (10 sessions)
  - Non-adaptive training (10 sessions)
  - No intervention

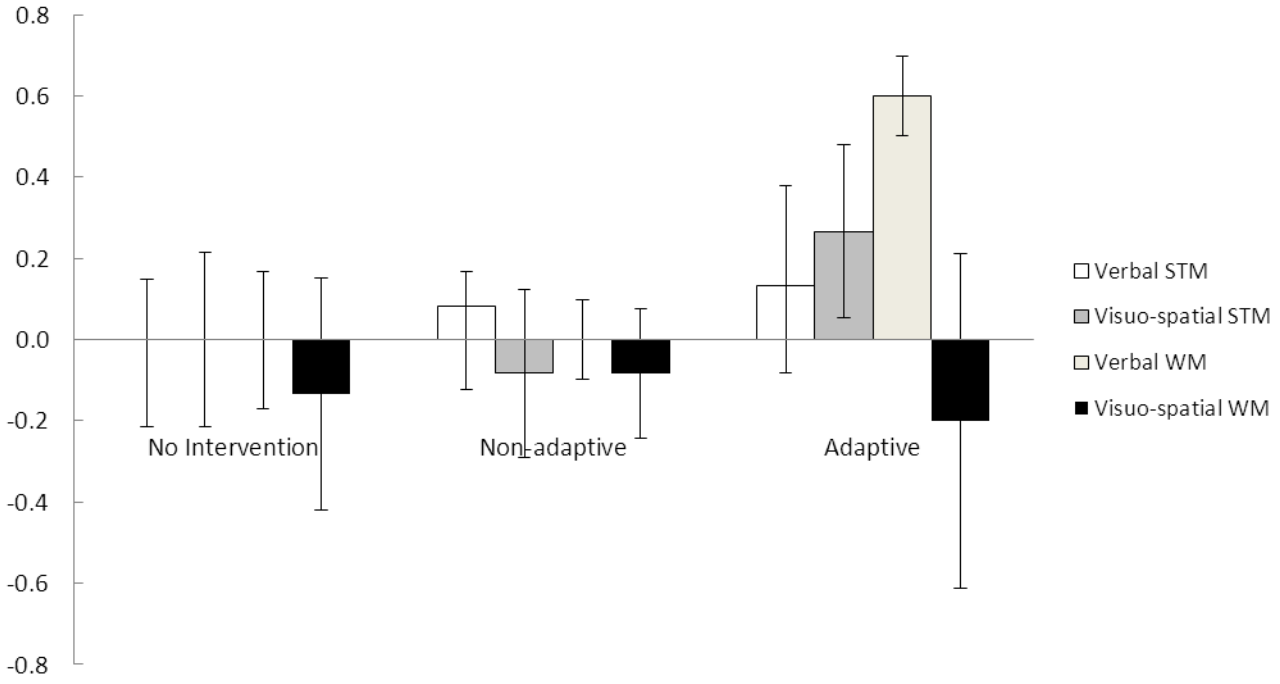
- AWMA (T1 & T2)
  - Verbal STM (digit recall)
  - Visuo-spatial STM (dot matrix)
  - Verbal WM (backward digit recall)
  - Visuo-spatial WM (Mr X)

- Asked about strategy use upon completion of each task

Working memory



Change in mean number of strategies reported T1 to T2



Significantly more strategies reported overall at T2 by adaptive group than control groups for verbal WM

Changes in the frequency of strategy use by group

	Verbal Short-Term Memory					
	Non-adaptive		Adaptive		No Intervention	
	Pre	Post	Pre	Post	Pre	Post
Rehearsal	14.29	14.29	21.43	21.43	13.33	20.00
Semantic	**7.14**	**0.00**	**14.29**	**0.00**	6.67	6.67
Visualisation	14.29	28.57	**14.29**	**0.00**	13.33	20.00
Chunking	21.43	28.57	28.57	71.43	26.67	26.67
Rhythm	7.14	7.14	7.14	7.14	0.00	0.00
Phonetically	7.14	7.14	0.00	0.00	**6.67**	**0.00**
Imagery	0.00	0.00	0.00	0.00	**6.67**	**0.00**

•Significant reductions in proportion of participants reporting use of some strategies, reflecting change for one or two participants. Small effect sizes.

•50% increase in no. of participants in adaptive group using chunking post-training.

Changes in the frequency of strategy use by group

Visuo-Spatial Short-Term Memory						
	Non-adaptive		Adaptive		No Intervention	
	Pre	Post	Pre	Post	Pre	Post
Rehearsal	**7.14**	**21.43**	7.14	14.29	13.33	6.67
Semantic	**7.14**	**0.00**	7.14	7.14	6.67	6.67
Visualisation	**57.14**	**35.71**	**64.29**	**28.57**	60.00	53.33
Chunking	0.00	0.00	0.00	50.00	6.67	13.33
Imagery	0.00	7.14	0.00	0.00	0.00	0.00
Concentrate	0.00	7.14	0.00	0.00	0.00	0.00
Verbal recoding	0.00	7.14	14.29	21.43	0.00	6.67

- Significant changes in proportion of participants reporting use of some strategies, reflecting change for a few participants (max 4).
- 50% increase in those in the adaptive group who reported using chunking post-training.

Changes in the frequency of strategy use by group

	Verbal Working Memory					
	Non-adaptive		Adaptive		No Intervention	
	Pre	Post	Pre	Post	Pre	Post
Rehearsal	14.29	14.29	35.71	42.86	20.00	26.67
Semantic	**7.14**	**0.00**	**7.14**	**0.00**	0.00	0.00
Visualisation	28.57	35.71	21.43	14.29	**26.67**	**46.67**
Chunking	7.14	14.29	7.14	78.57	13.33	13.33
Rhythm	**7.14**	**0.00**	**0.00**	**7.14**	**6.67**	**0.00**
Phonetically	**7.14**	**0.00**	0.00	0.00	**13.33**	**0.00**
Imagery	0.00	0.00	0.00	0.00	**6.67**	**0.00**
Concentrate	**0.00**	**7.14**	**7.14**	**0.00**	0.00	0.00
Speed	0.00	0.00	**0.00**	**7.14**	0.00	0.00

- Significant changes in proportion of participants reporting use of some strategies, reflecting change for a few participants (max 3).

- 70% increase in those in the adaptive group who reported using chunking post-training.

Changes in the frequency of strategy use by group

Visuo-Spatial Working Memory

	Non-adaptive		Adaptive		No Intervention	
	Pre	Post	Pre	Post	Pre	Post
Rehearsal	**0.00**	**7.14**	0.00	0.00	6.67	6.67
Semantic	14.29	7.14	21.43	14.29	20.00	13.33
Visualisation	28.57	21.43	14.29	14.29	26.67	20.00
Chunking	0.00	0.00	0.00	0.00	**0.00**	**13.33**
Imagery	7.14	7.14	0.00	0.00	0.00	0.00
Concentrate	0.00	0.00	**7.14**	**0.00**	**6.67**	**0.00**
Verbal recoding	0.00	0.00	**7.14**	**0.00**	0.00	0.00
Inhibiting irrelevant info	0.00	0.00	0.00	0.00	**6.67**	**0.00**

- Significant changes in proportion of participants reporting use of some strategies, reflecting change for a few participants (max 2).

- No clear pattern of change.

Summary

- 10 sessions of adaptive training
  - significant improvements in untrained tests of WM
  - changes in the number and types of strategies participants use to complete these tasks
  - significant increase in use of chunking strategies to complete verbal and VS STM and verbal WM tasks

Summary

- Training promotes use of effective strategies that in turn boosts WM performance
  - Strategy mediation hypothesis (McNamara & Scott, 2001)
- Training increases WM capacity, freeing resources to employ effortful strategies
  - Strategy-as-effect hypothesis (Dunlosky & Kane, 2007)
- Not mutually exclusive

Summary

- Adds to evidence that current training methods promote development of highly task-specific strategies
  - Span-like training: Transfer only to tasks that are similar in structure to the trained activities (Gathercole, Dunning & Holmes, in prep)
  - N-back training: No transfer to complex span task performance (Jaeggi et al., 2011)

- Can this explain the absence of transfer?
  - Strategy affordance hypothesis (Bailey, Dunlosky & Kane, 2008)
    - relationship between memory span and other activities is mediated by strategy use only when both tasks afford the same strategies
    - strategies developed through training do not necessarily overlap with the strategies used in working memory demanding situations in everyday life

Future directions

- Transfer
  - Training programs need to provide practice that encourages recruitment of a variety of strategies across a range of tasks that map more directly on to the challenging everyday situations in which working memory is used
  - Or make explicit how strategies can be deployed in other contexts