Rehearsal and the development of working memory

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Rehearsal and the development of WM

Outline

- Rehearsal – its relation to short-term memory, working memory, and Piagetian theory
- The developmental of rehearsal: Evidence from studies of short-term memory in individuals with atypical development
- Examining rehearsal in working memory
- A qualitative developmental shift in rehearsal?

Rehearsal: STM, & WM, & Piaget

Rehearsal:

Offsets time-based forgetting caused by trace decay

Its efficiency depends on its rate

Implicated in the recoding of visual material

Potential markers:

The word length effect

Speech rate / span correlations

A phonological similarity effect with visual presentation

Rehearsal: STM, & WM, & Piaget

Short-term memory and working memory:

Short-term memory (STM) - holding information active in mind (tested by ‘simple span’ tasks)

Working memory (WM) - holding information active in mind in the face of potentially distracting processing (tested by ‘complex span’ tasks)

So WM tasks require short-term storage (STM) in addition to other factors (Bayliss et al., 2005)

Rehearsal: STM, & WM, & Piaget

A Piagetian perspective?

"Too little research has been done on the memory of the child, and what research there has been has centered primarily on the measuring of performance" (Piaget & Inhelder, 1969, p. 80)

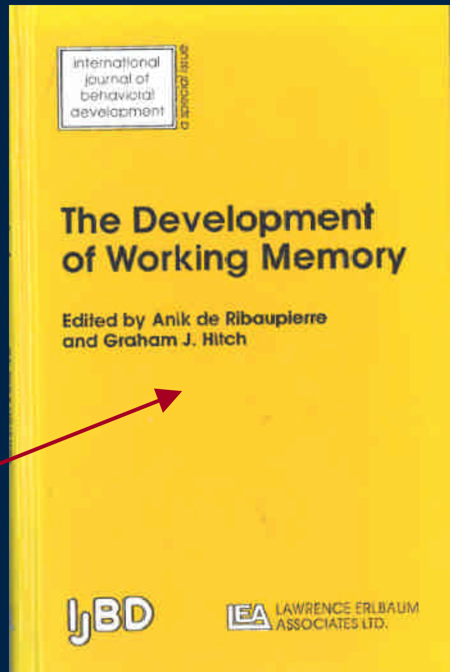
Rehearsal: STM, & WM, & Piaget

"It is customary to represent memory as a system of coding and decoding, which naturally assumes the intervention of a code. But curiously enough this code has been studied very little, as if it were taken for granted that the code stays the same throughout development" (Piaget, 1968, pp. 1-2)

Rehearsal: STM, & WM, & Piaget

The claim:

"the youngest children may not use rehearsal, at least not in the form that older children and adults use it" (Henry, 1994, p. 53)



Lip movements in STM tasks not observed in children before 7 (Flavell et al., 1966)

The development of rehearsal

Evidence for the onset of rehearsal around 7?:

The word length effect

Speech rate / span correlations

A phonological similarity effect with visual presentation

The development of rehearsal

Evidence for the onset of rehearsal around 7?:

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The development of rehearsal

The word length effect (WLE) often thought to reflect processes (time-based decay of non-rehearsed items) *within* verbal STM

An alternative – Cowan et al. (1992):

Output effects – the quicker that words can be outputted the less time 'still-to-be-recalled' items have to wait

The development of rehearsal

What happens when you remove output demands?

Baddeley et al. (2002) - still get a WLE, albeit reduced, in adults using a recognition task

Henry (1991) – 7-year-olds show a WLE with probed recall, 5-year-olds do not (see also Turner et al., 2000)

Consistent with a qualitative shift around 7, but methodological concerns:

The development of rehearsal

Henry gave shorter lists to her younger group (3 & 4 items rather than 4 & 5) to equate levels of performance

Understandable - but in probed recall you get marked recency (Waugh & Norman, 1965)

Relatively more trials likely to give rise to ceiling effects, and reduced power to observe experimental effects, in the younger group

The development of rehearsal

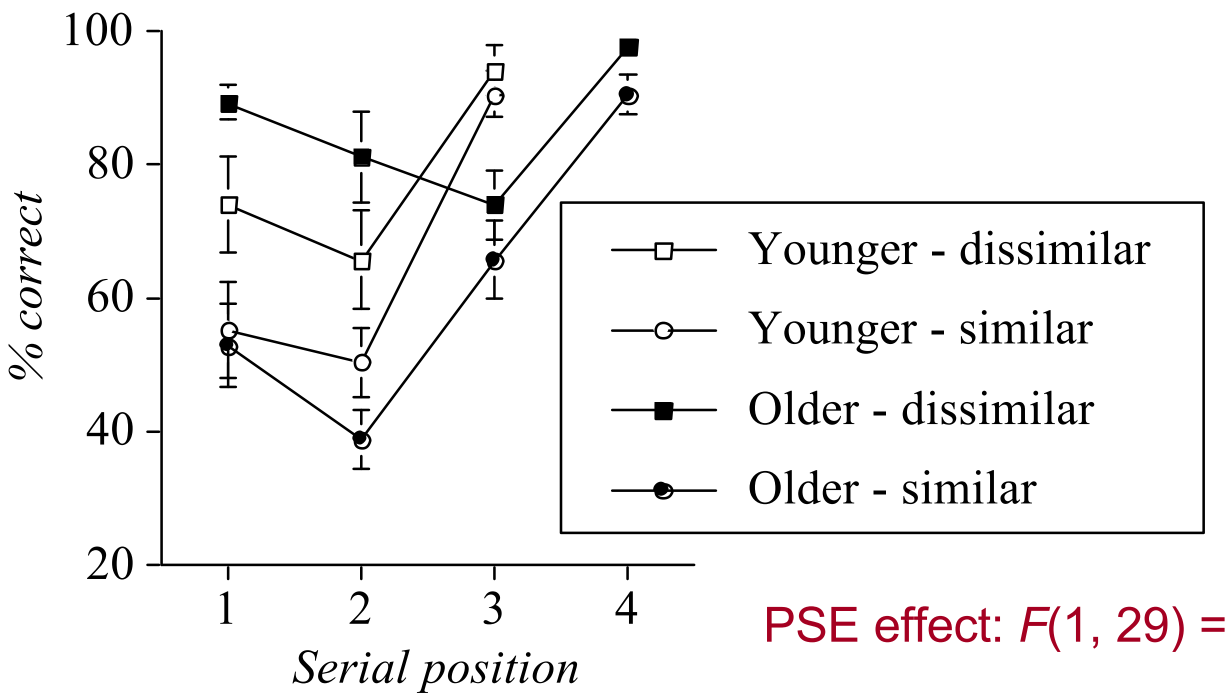
Jarrold et al. (2008) - is probed recall potentially insensitive?

17 5- & 6-year-olds

17 8- & 9-year-olds

Probed recall with auditorily presented phonologically similar and disimilar lists (3 items for younger group, 4 items for older). Each position 5 times

The development of rehearsal



PSE effect: $F(1, 29) = 44.13$

Interaction: $F(1, 29) = 4.09$

On a recognition test see no interaction, $F(1, 29) = 0.05$

The development of rehearsal

This evidence from the PSE implies that probed recall is relatively insensitive with young children

Casts doubt on Henry's WLE evidence

We've yet to do a direct test of the apparent change in magnitude of the WLE in children across ages, but some preliminary evidence:

The development of rehearsal

Jarrold et al. (2000a) – probed recall in individuals with Down syndrome

14 individuals with Down syndrome (DS)

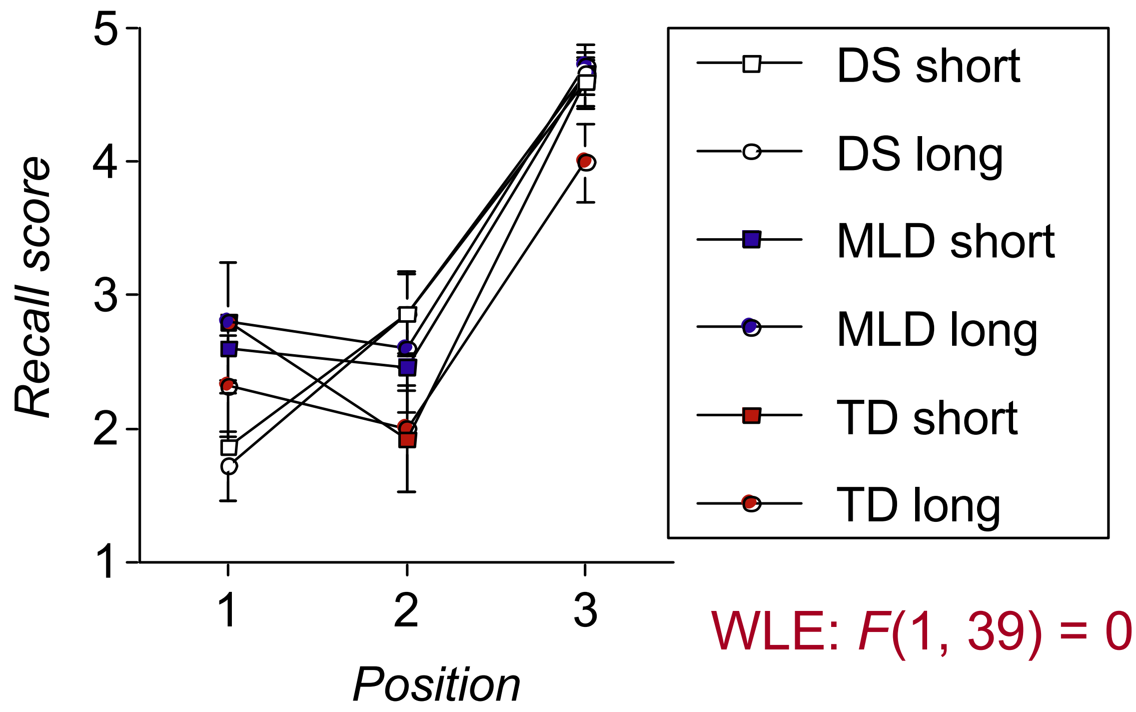
14 with Moderate learning difficulties (MLD)

14 typically developing (TD) 5-year-olds

Probed recall with short and long duration words

– 3 item lists, each position probed 5 times

The development of rehearsal



WLE: $F(1, 39) = 0.47$

No suggestion of a WLE at early serial positions in these children functioning below the 7 year age equivalent level

The development of rehearsal

Evidence for the onset of rehearsal around 7?:

The word length effect

Speech rate / span correlations

A phonological similarity effect with visual presentation

See Gathercole et al. (1994)

The development of rehearsal

Jarrold et al. (2004)

16 individuals with Williams syndrome (WS)

16 8- to 10-year old TD children matched for VMA

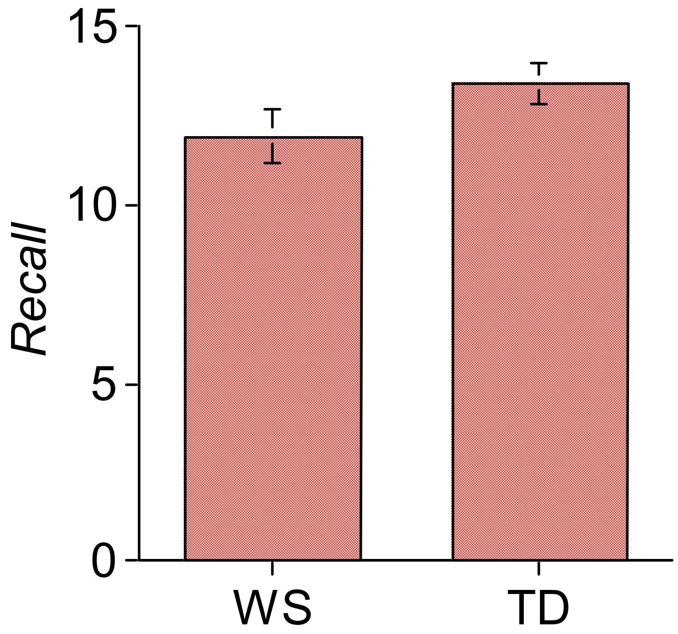
14 individuals with Down syndrome (DS)

14 4- to 5-year old TD children matched for VMA

Verbal short-term memory spans & articulation rates

The development of rehearsal

WS – verbal short-term memory performance:



F(1, 29) = 6.60

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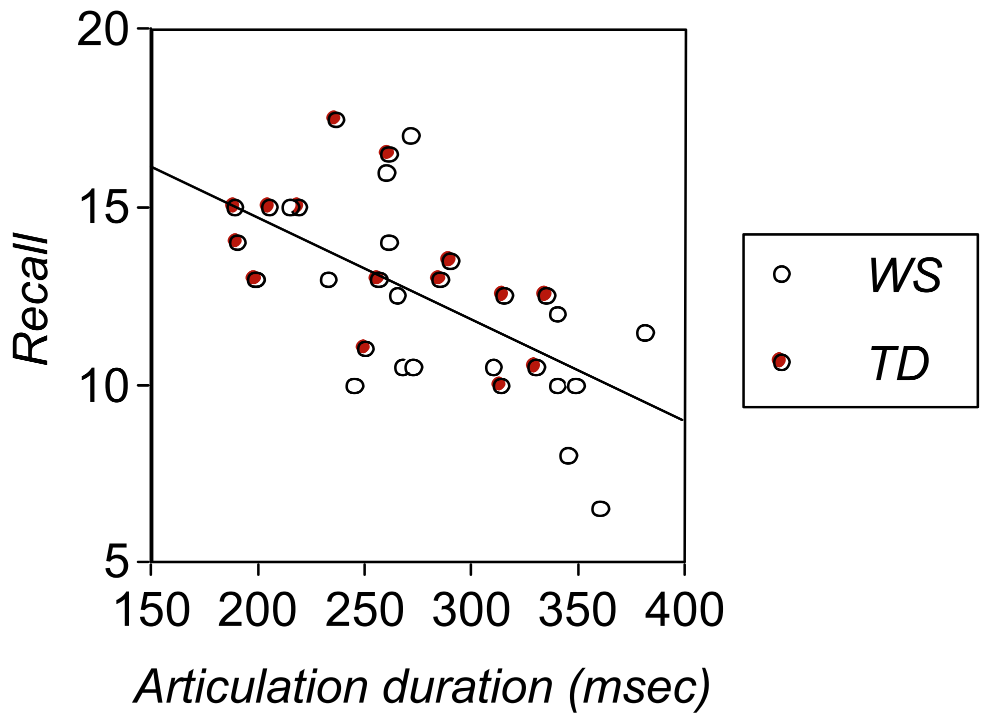
WS - relation to speech rate:

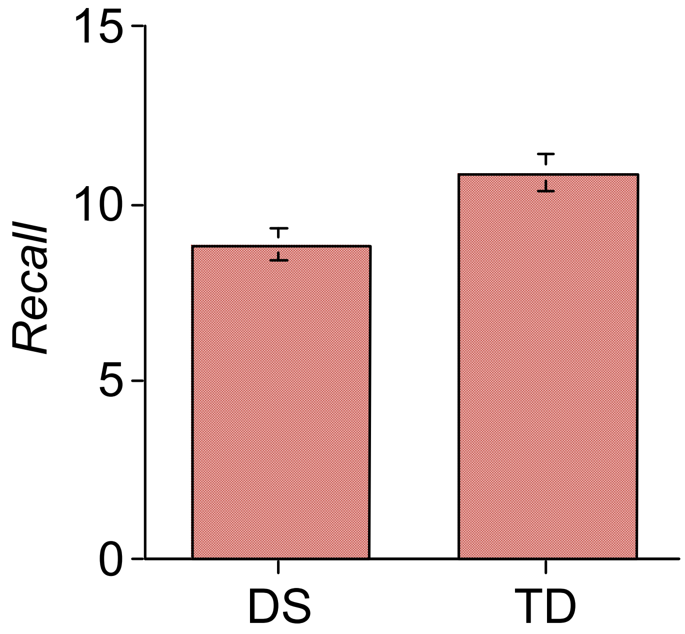


r = -.62

F(1, 28) = 0.93

The development of rehearsal

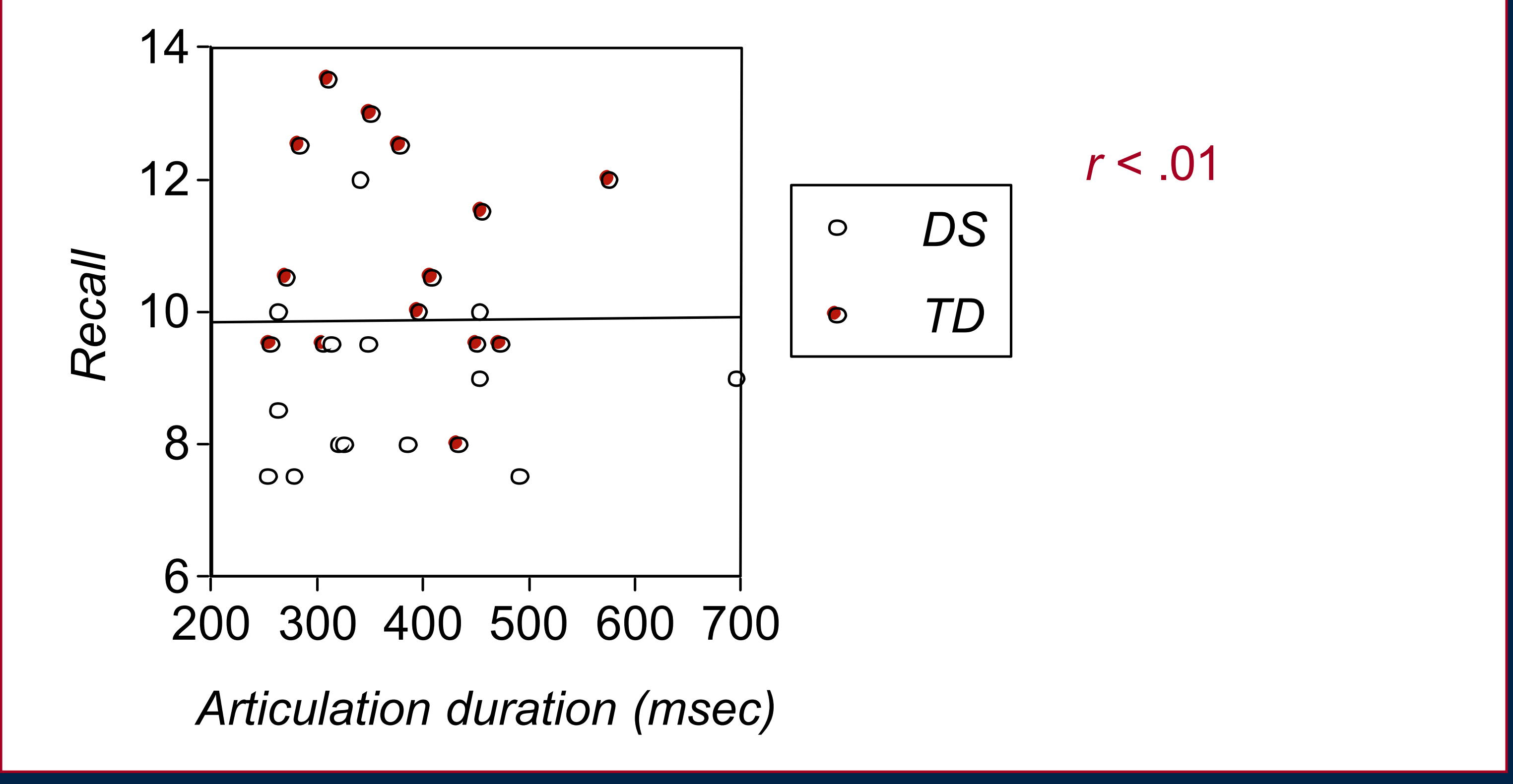
DS – verbal short-term memory performance:



F(1, 25) = 12.12

The development of rehearsal

DS - relation to speech rate:



The development of rehearsal

Evidence for the onset of rehearsal around 7?:

The word length effect

Speech rate / span correlations

A phonological similarity effect with visual presentation

See Hitch et al. (1989)

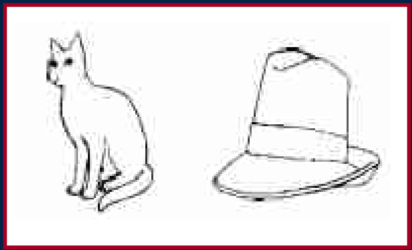
The development of rehearsal

Williams et al. (2008)

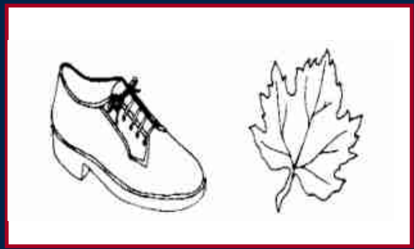
Children with autism (*n* = 25) or other (non-specific) learning difficulties (*n* = 20)

Visually presented stimuli for verbal recall, in 3 conditions:

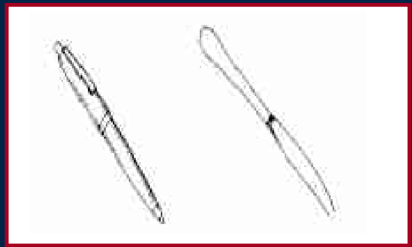
Phonologically similar



Control

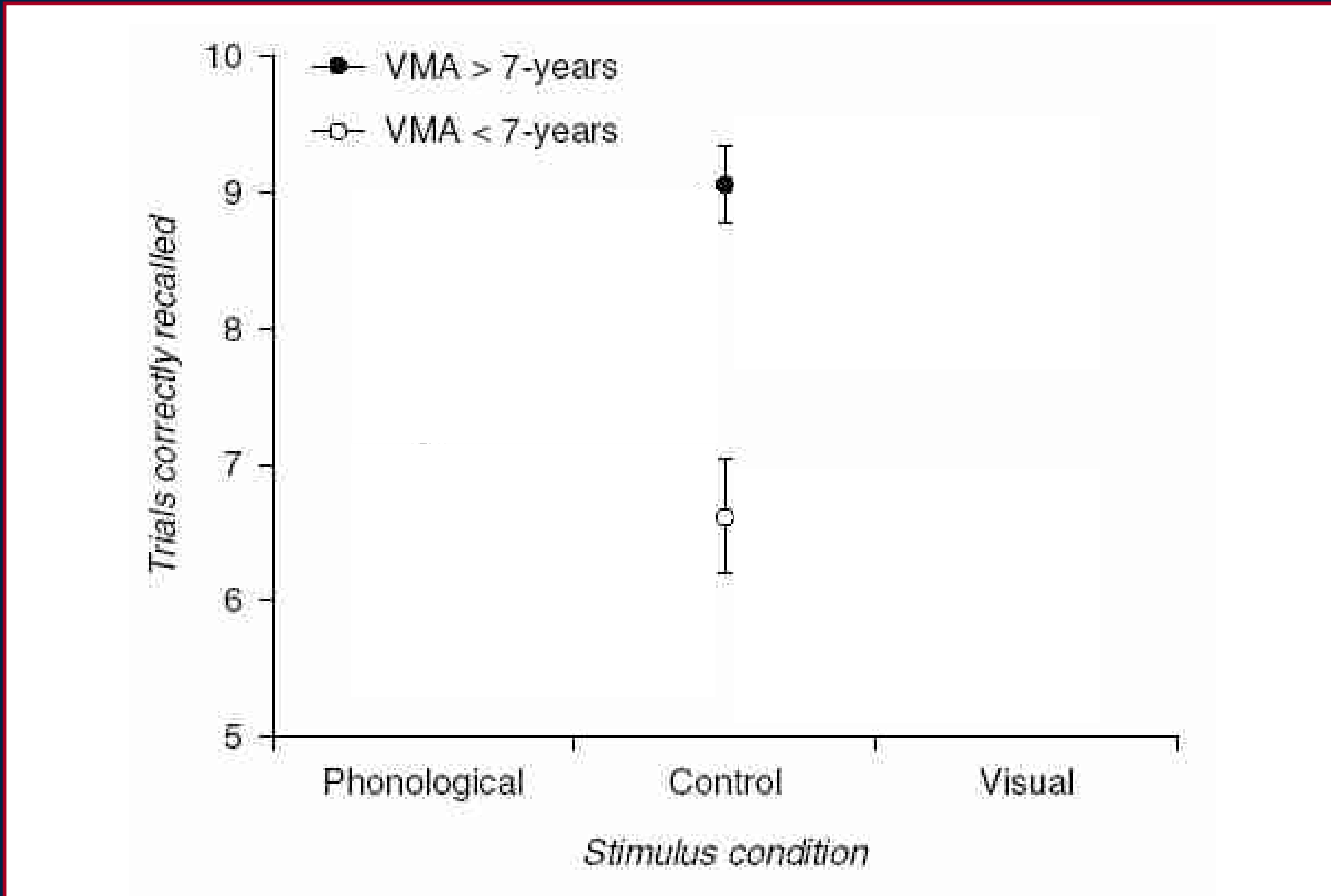


Visually similar



The development of rehearsal

Results:



The development of rehearsal

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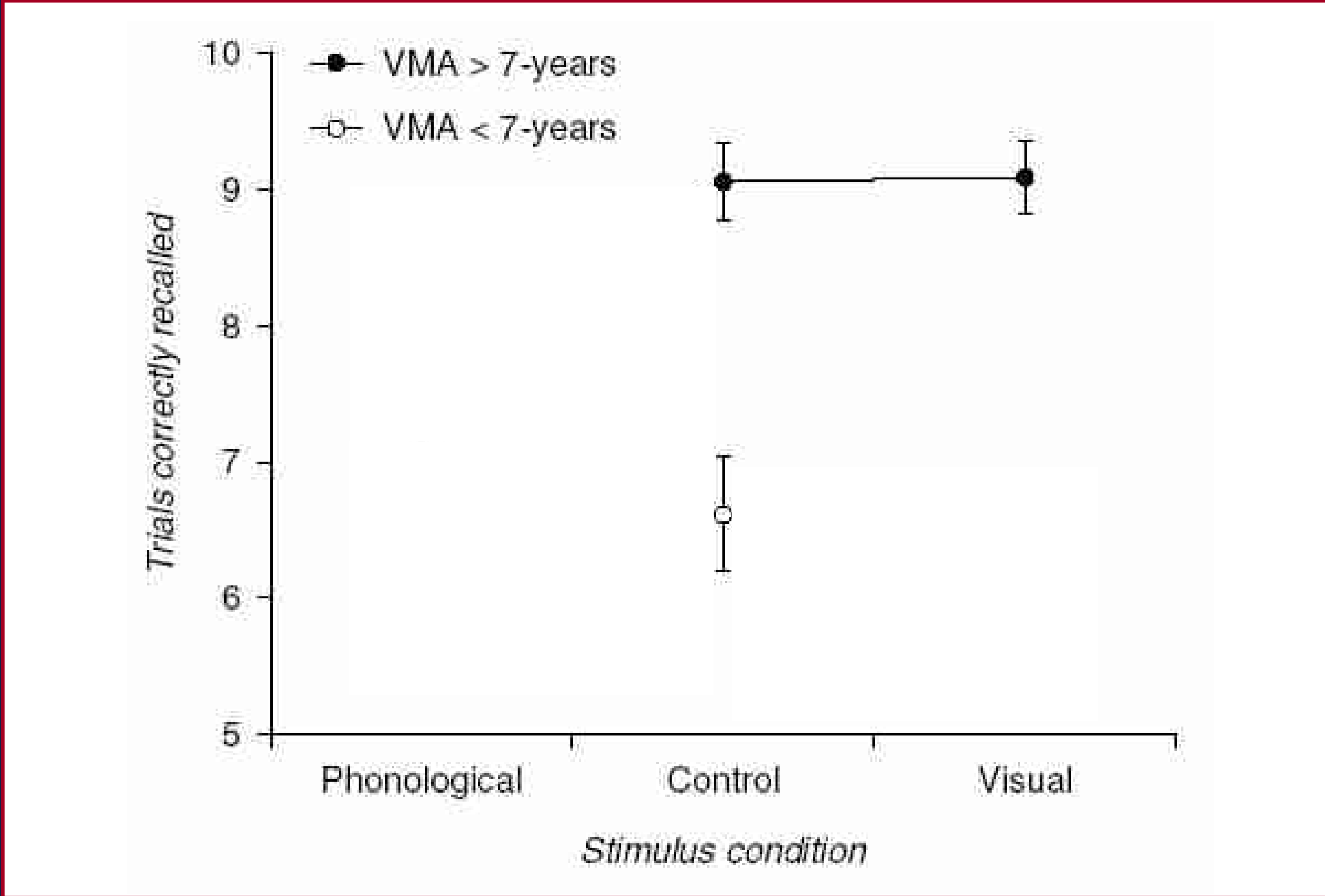
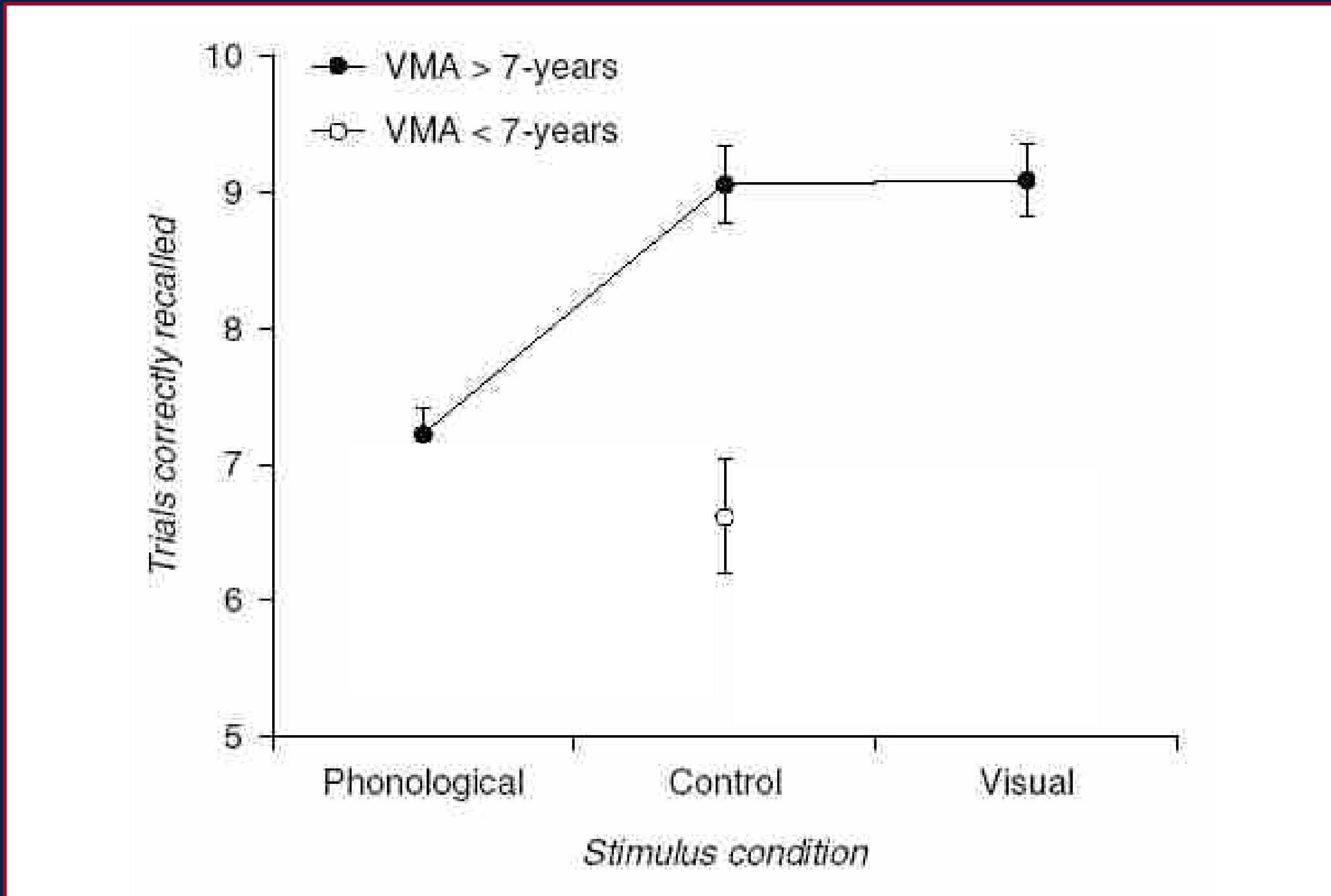


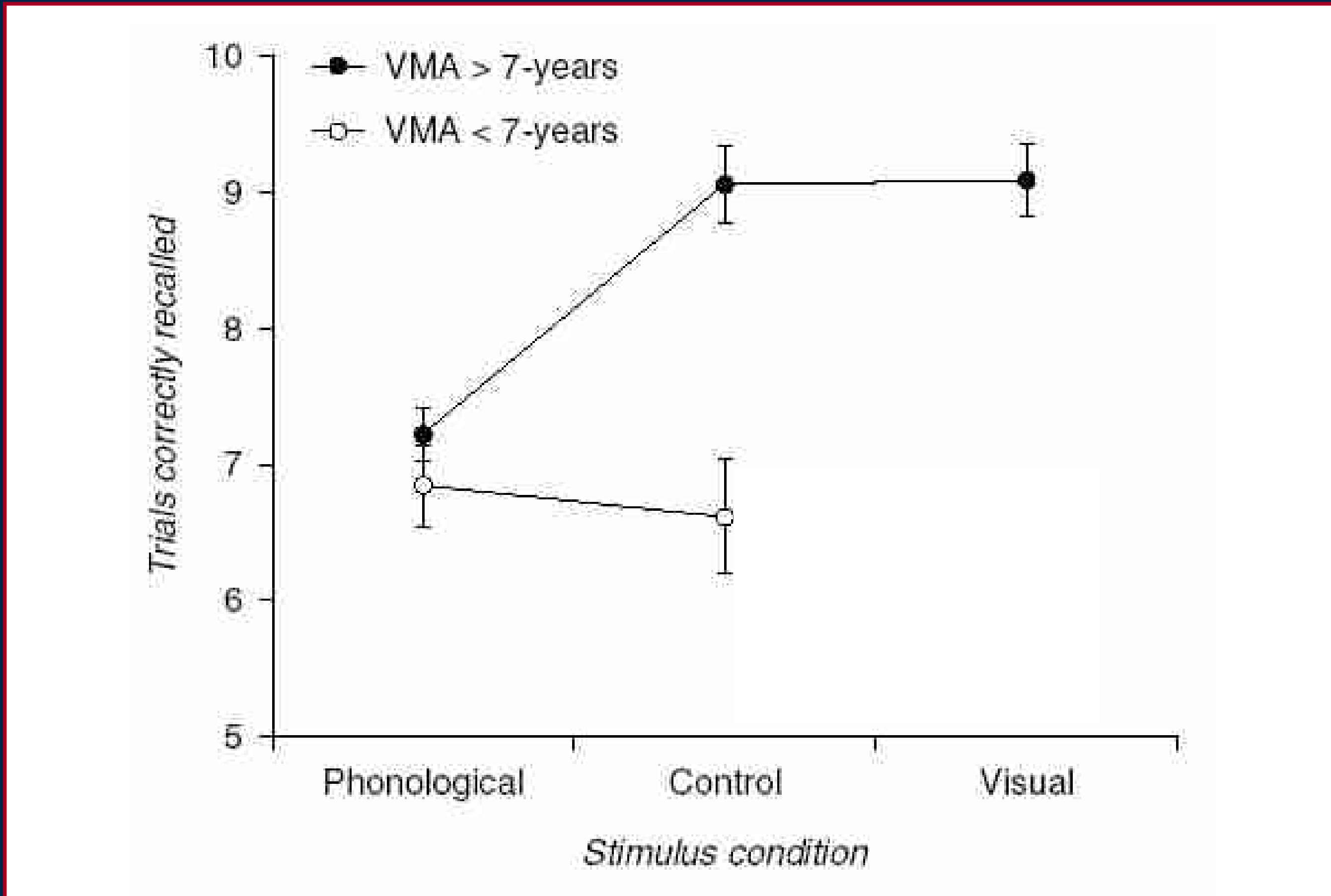
The development of rehearsal

Results:



The development of rehearsal

Results:



The development of rehearsal

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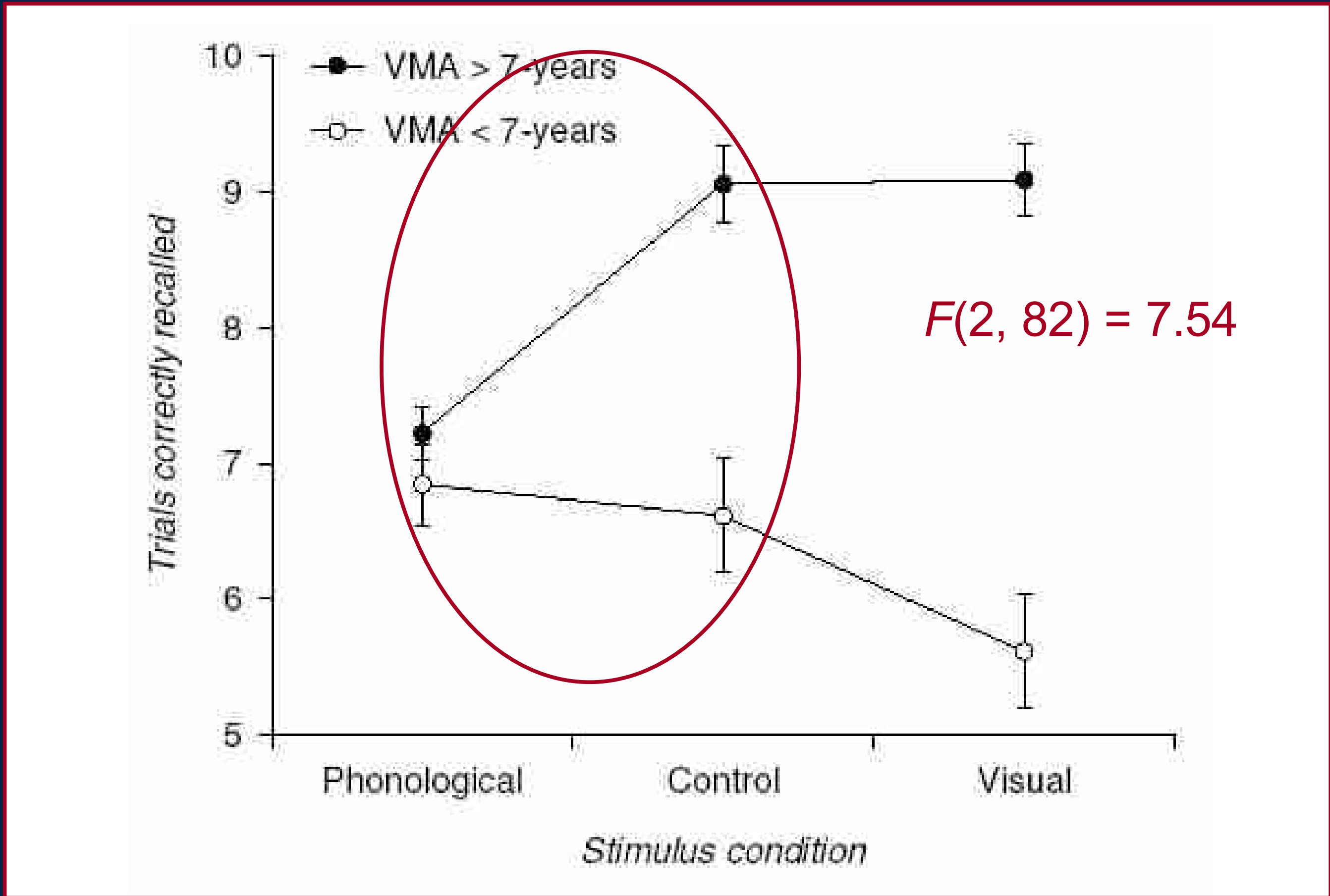


The development of rehearsal

The word length effect

Speech rate / span correlations

A phonological similarity effect with visual presentation

Evidence of a change in extent of rehearsal around 7-years

Or, more accurately, around 7-years age equivalent level

Examining rehearsal in working memory

Working memory (WM) - holding information active in mind in the face of potentially distracting processing (tested by 'complex span' tasks)

Case et al. (1982)

Examining rehearsal in working memory

Working memory tasks (complex span) are often better predictors of academic abilities that short-term memory tasks (simple span) (Oberauer et al., 2005; though see Unsworth & Engle, 2007)

Why?

Something to do with the addition of processing

Blocks rehearsal?

Introduces the need to switch between phases?

(Barrouillet et al., 2007; Towse & Hitch, 2007)

Examining rehearsal in working memory

Tam et al. (submitted)

Examine these issues in samples of children who vary in rehearsal status

- Does processing block rehearsal in working memory paradigms?
- Is there a switch cost in complex span?
- Does an absence of rehearsal in young children mean that short-term memory measures are comparable predictors of academic abilities (Cowan et al., 2005)?

Examining rehearsal in working memory

Participants:

110 5- to 6-year-olds (young group)

90 7- to 8-year-olds (old group)

Procedure:

Measures of achievement (reading and maths)

Test of PSE effect with visual presentation

4 other memory measures –

Examining rehearsal in working memory

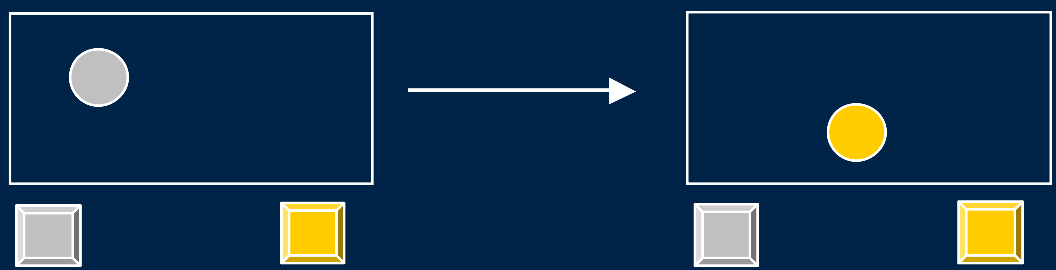
4 other memory measures:

Storage

1-syllable, low AOA, concrete words, presented both visually and auditorily for 1s

Processing

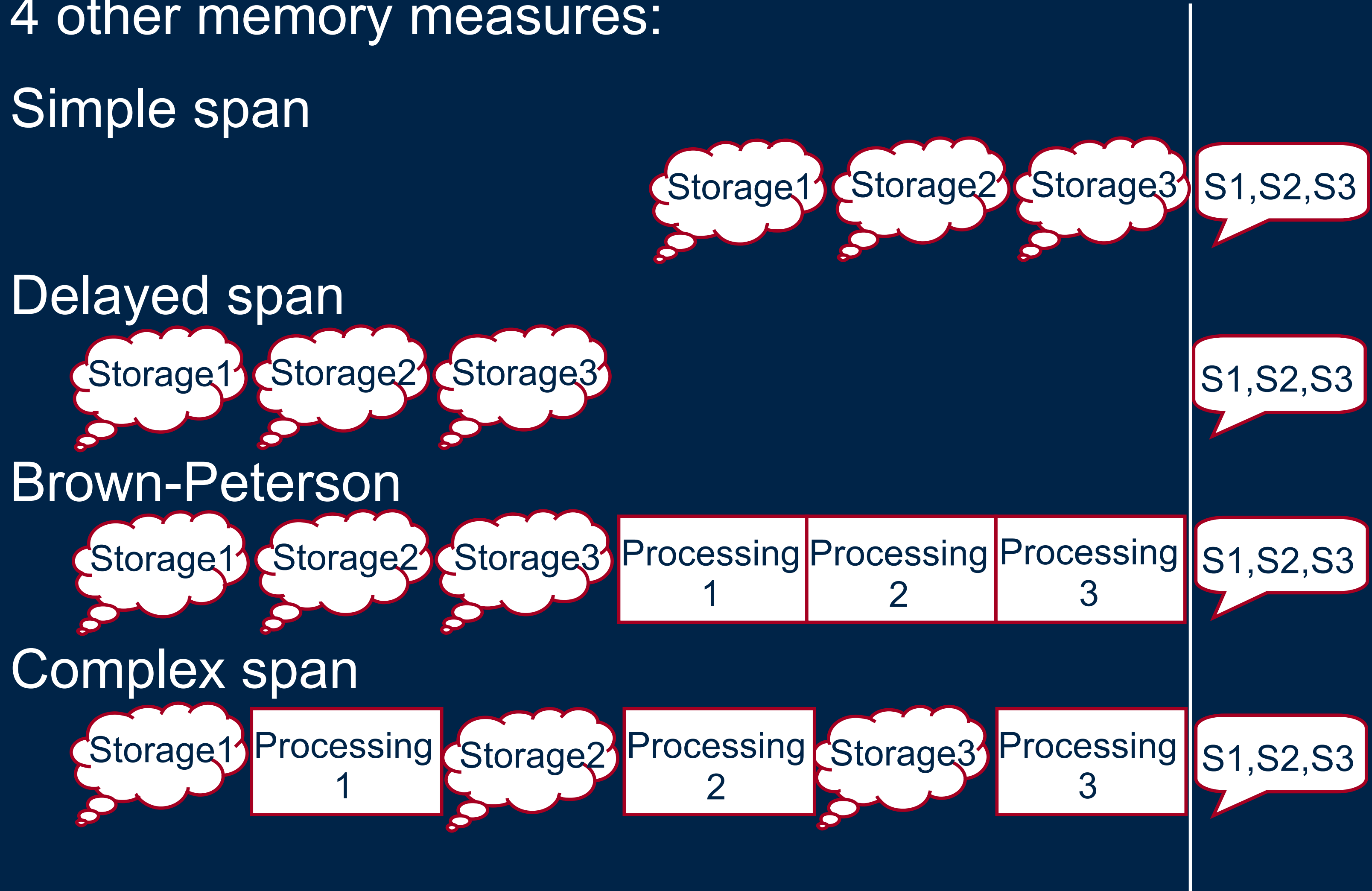
Each processing ‘episode’ lasts 3s, and consists of *continuous* coin collecting operations



Examining rehearsal in working memory

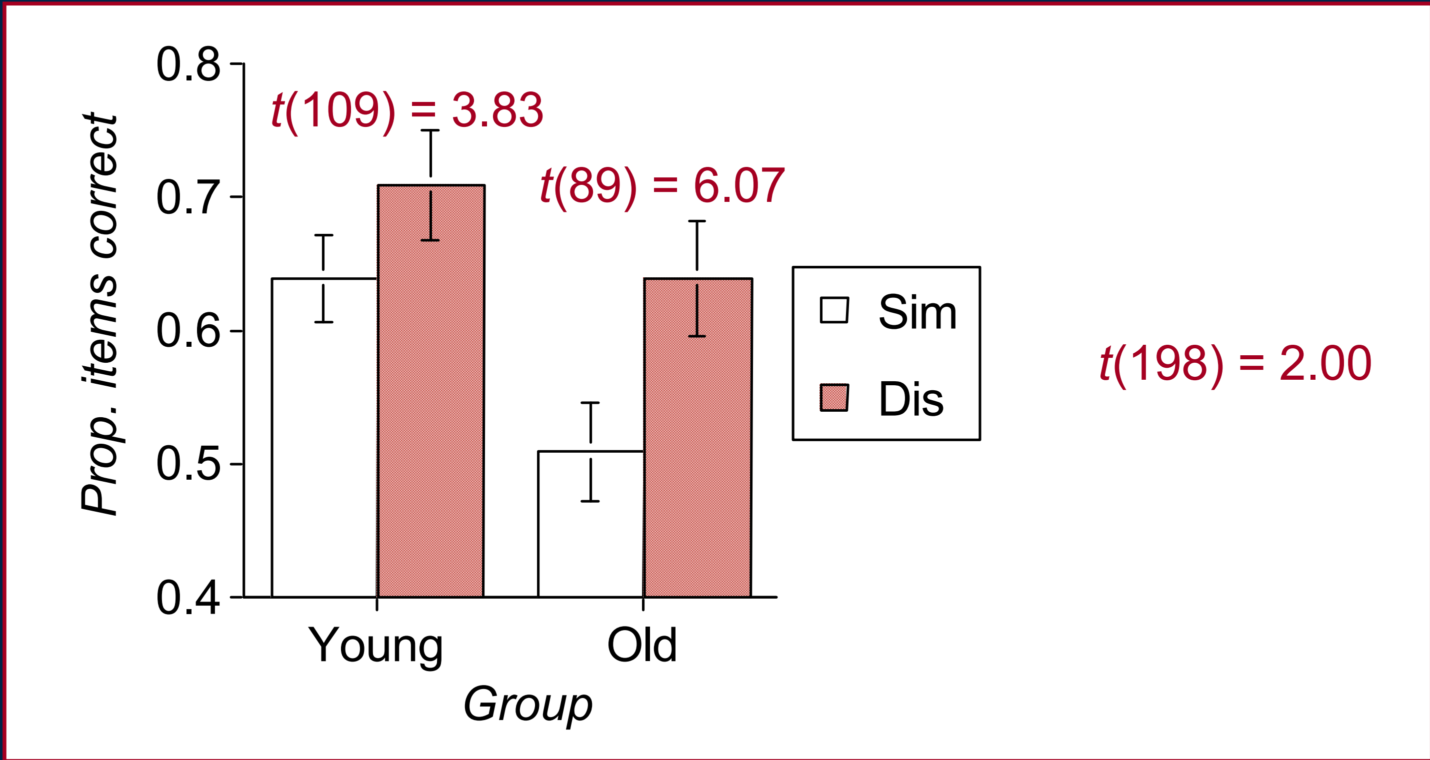
4 other memory measures:

Simple span



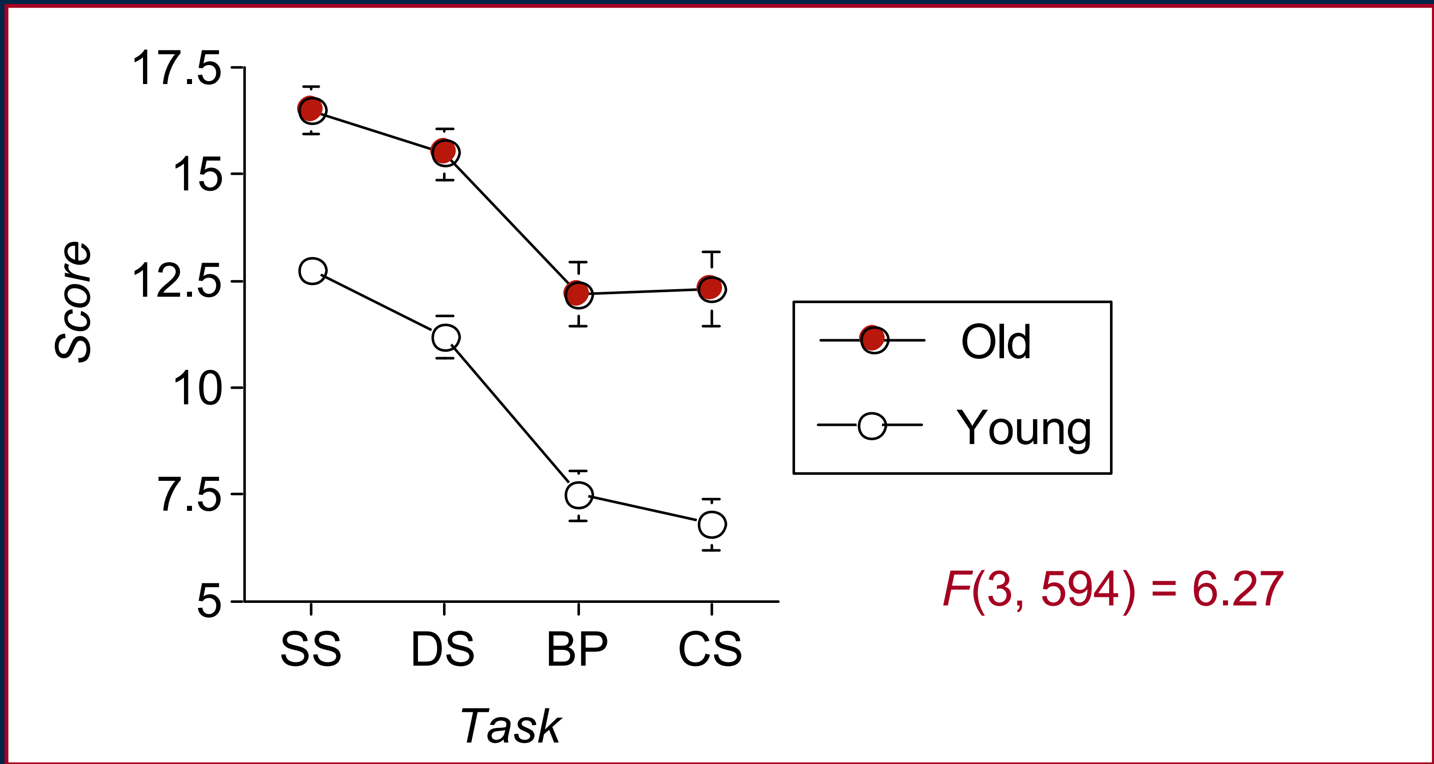
Examining rehearsal in working memory

Phonological similarity effect:



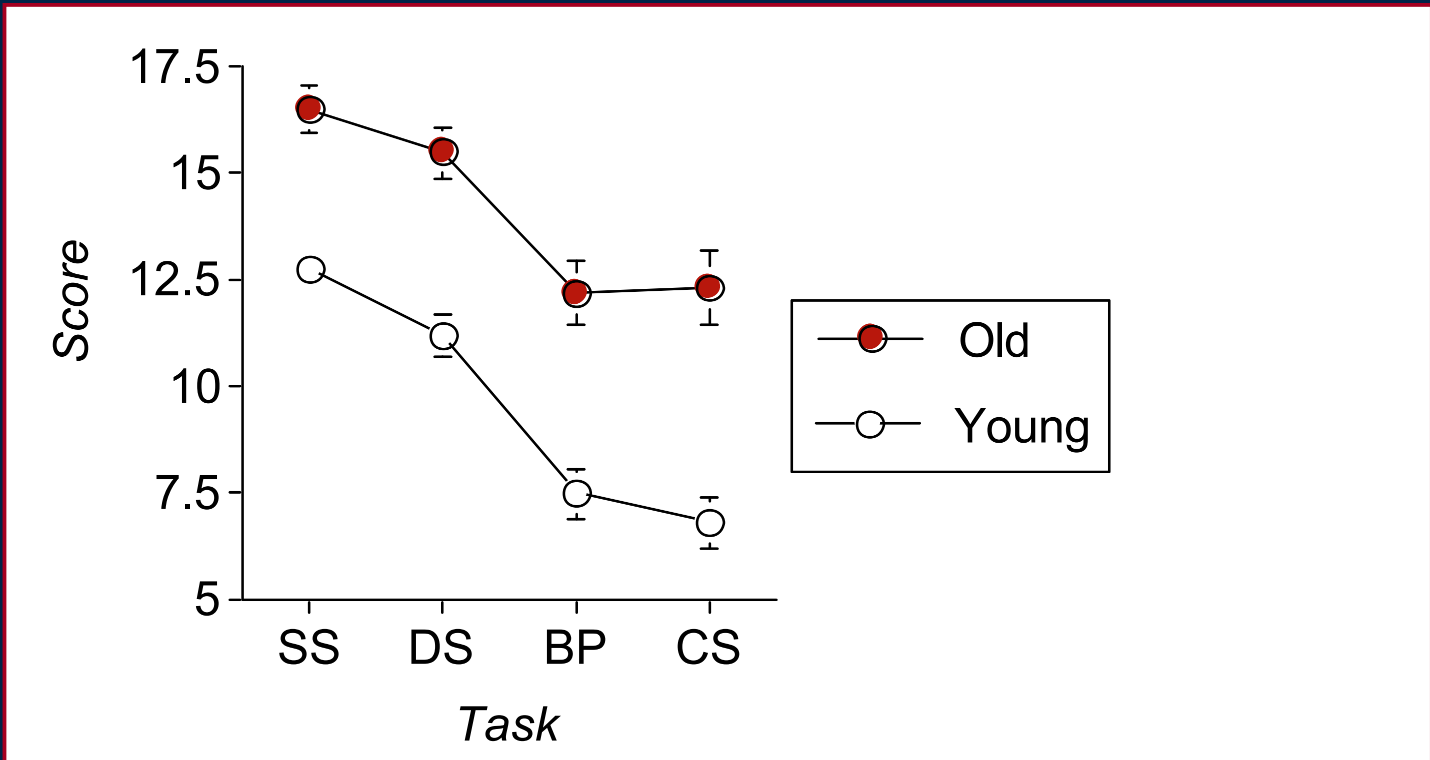
Examining rehearsal in working memory

4 other memory measures:



Examining rehearsal in working memory

- Does processing block rehearsal in working memory paradigms?



Examining rehearsal in working memory

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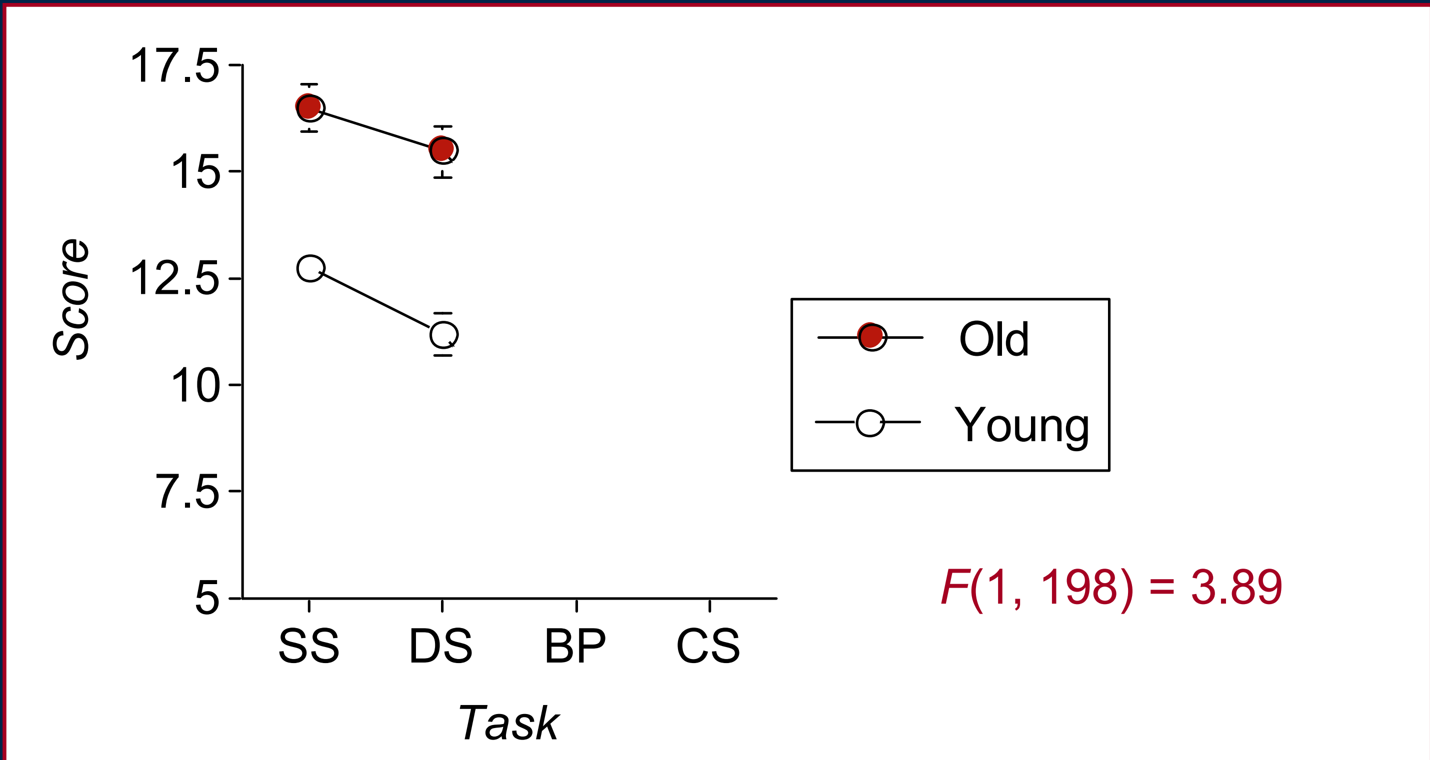
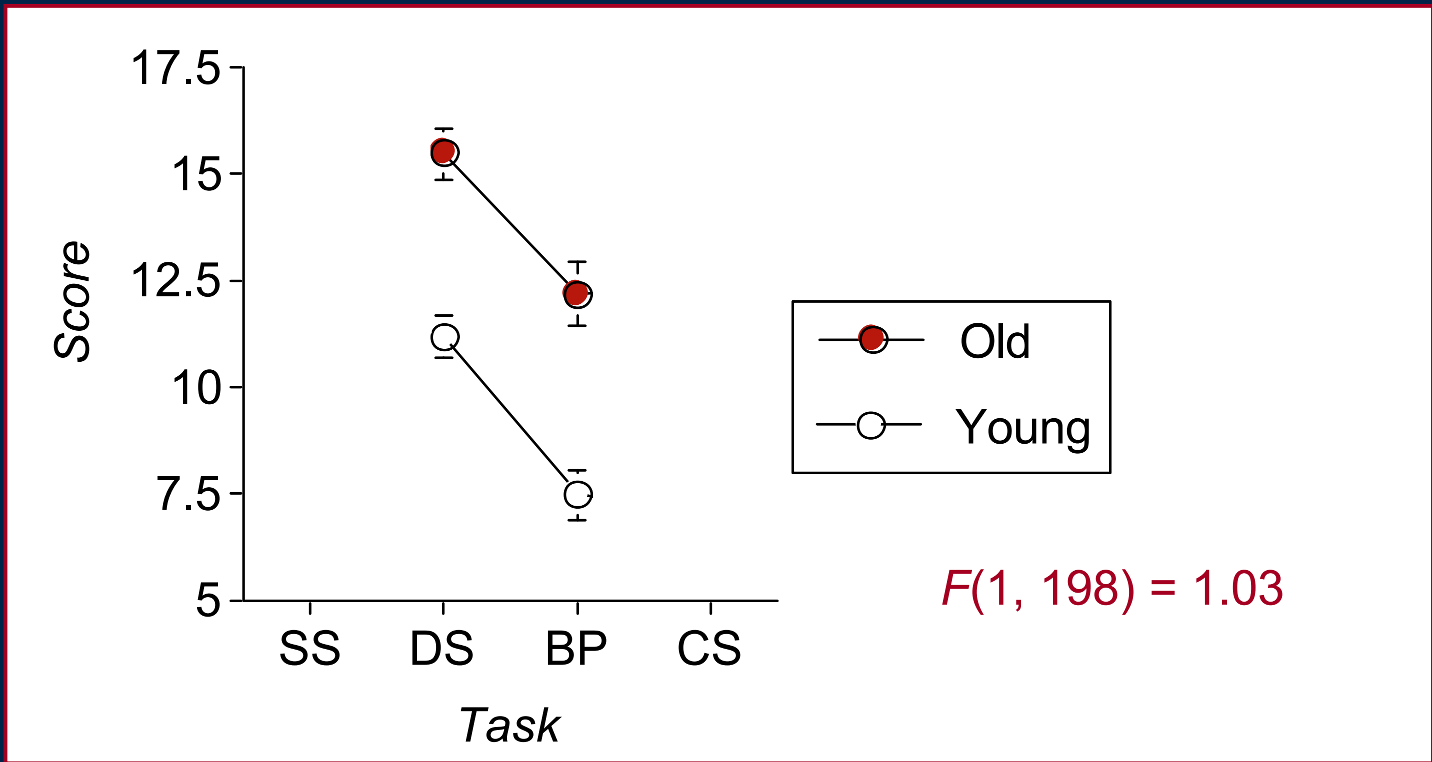


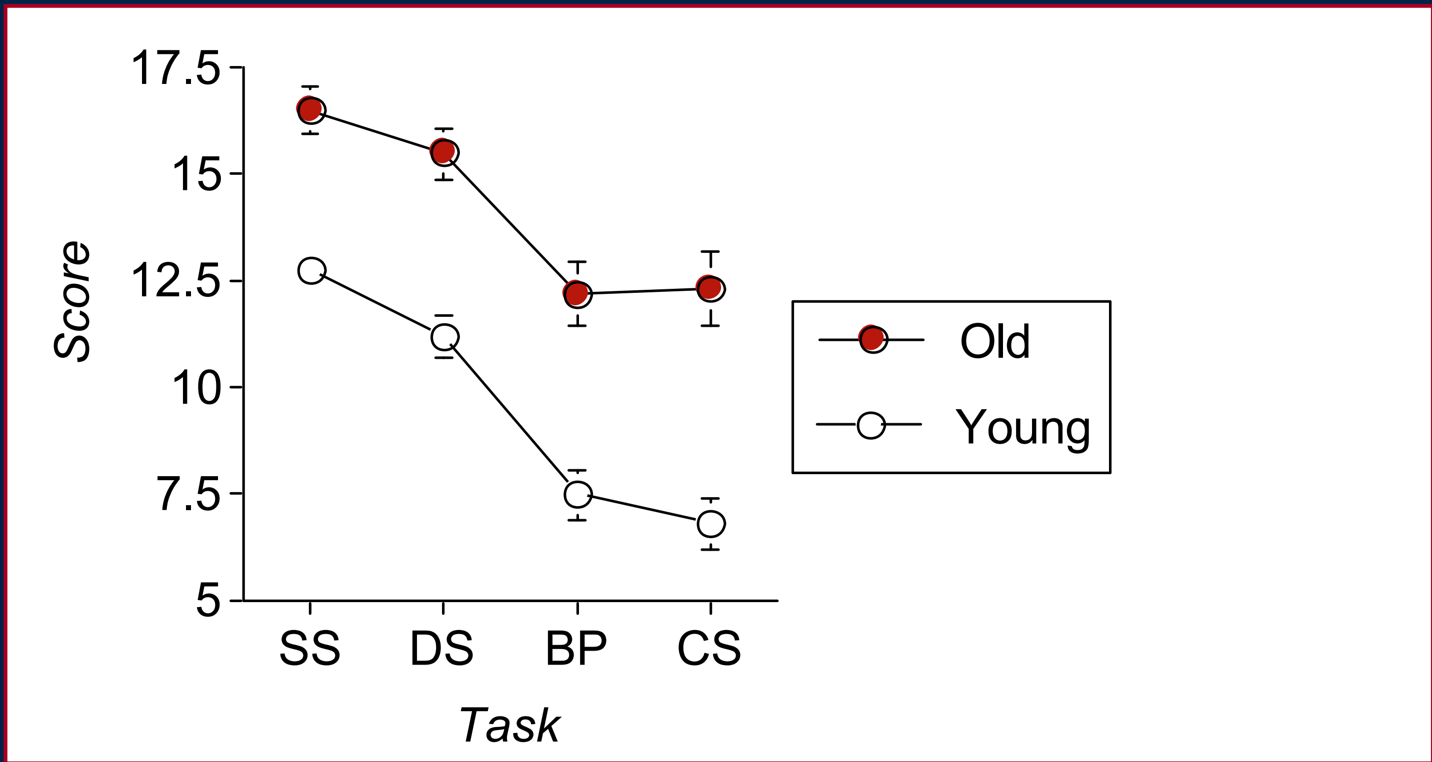
Examining rehearsal in working memory

- Does processing block rehearsal in working memory paradigms?



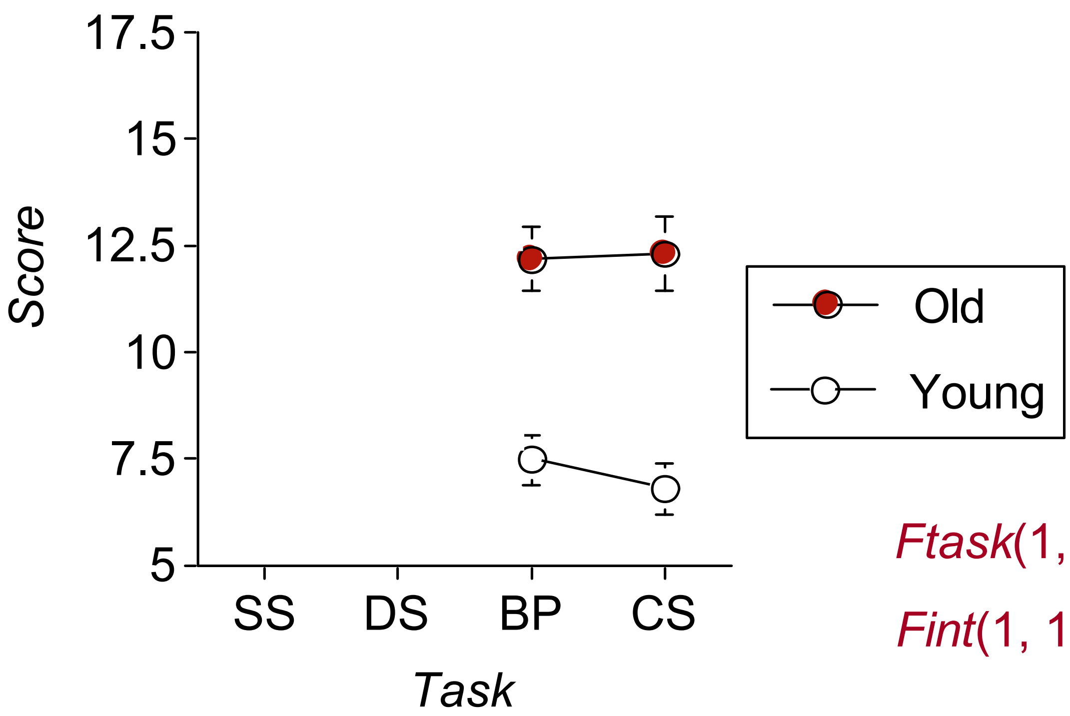
Examining rehearsal in working memory

- Is there a switch cost in complex span?



Examining rehearsal in working memory

- Is there a switch cost in complex span?



Ftask(1, 198) = 1.26

Fint(1, 198) = 2.72

Examining rehearsal in working memory

- Does an absence of rehearsal in young children mean that STM measures are comparable predictors of academic abilities?

Examining rehearsal in working memory

Inter-relations between memory measures:

Y	DS	BP	CS	PSE
SS	.70	.49	.45	.11
DS		.52	.60	.08
BP			.52	.01
CS				.07

Examining rehearsal in working memory

Inter-relations between memory measures:

O	DS	BP	CS	PSE
SS	.77	.52	.59	.28
DS		.62	.59	.27
BP			.55	.14
CS				.03

Examining rehearsal in working memory

Predictors of a composite measure of attainment:

Young group		Old group	
SS	.42	SS	.60
DS	.41	DS	.66
BP	.40	BP	.48
CS	.38	CS	.47

Examining rehearsal in working memory

Conclusion 1: Does processing block rehearsal in working memory paradigms?

- Evidence that our two age groups differ in the extent to which they engage in phonological recoding (rehearsal)
- This relates to a differential effect of an unfilled delay on recall - less efficient rehearsers maintain less well

Examining rehearsal in working memory

But, the groups show comparable effects of filling that delay (if older individuals are more likely to rehearse in an unfilled delay, then blocking rehearsal should have a greater effect)

Greater domain-general interference / dual task effects in younger individuals?

Younger individuals may be more likely to maintain information visually, and so are affected by a visually-based processing task?

Examining rehearsal in working memory

Conclusion 2: Is there a switch cost in complex span?

- No evidence that individuals recall less information in CS than in BP, which are equated for amount of processing and storage, but which differ in degree of switching

Might there be a switch cost which is hidden by a ‘temporal distinctiveness’ benefit to storage items in complex span?

Examining rehearsal in working memory

Conclusion 3: Does an absence of rehearsal in young children mean that STM measures are comparable predictors of academic abilities?

- Among younger individuals SS is as good a predictor as CS, replicating Cowan et al. (1995)

- But not the case that older individuals show the adult pattern - more rehearsal in this group does not improve the CS-attainment correlation

Examining rehearsal in working memory

Delayed span a particularly good predictor of attainment, especially in the older individuals

Delayed span presumably provides the greatest opportunity for rehearsal

Is variance in working memory ability in this age group (7s to 8s) driven mainly by variance in rehearsal use/efficiency?

A qualitative developmental shift in rehearsal?

Seen “evidence of a change in extent of rehearsal …
around 7-years age equivalent level”

But is this qualitative or quantitative change?

A qualitative developmental shift in rehearsal?

Previous researchers have tended to argue for a qualitative shift:

"Children … do not seem to rehearse before the age of seven years" (Henry, 1991, p. 49)

"young children do not use subvocal rehearsal" (Gathercole et al., 1994, p. 206)

"at around 5 years of age … the control processes necessary for [visual inputs] to gain access to the phonological storage component have yet to develop" (Hitch et al., 1989, pp. 183-184)

A qualitative developmental shift in rehearsal?

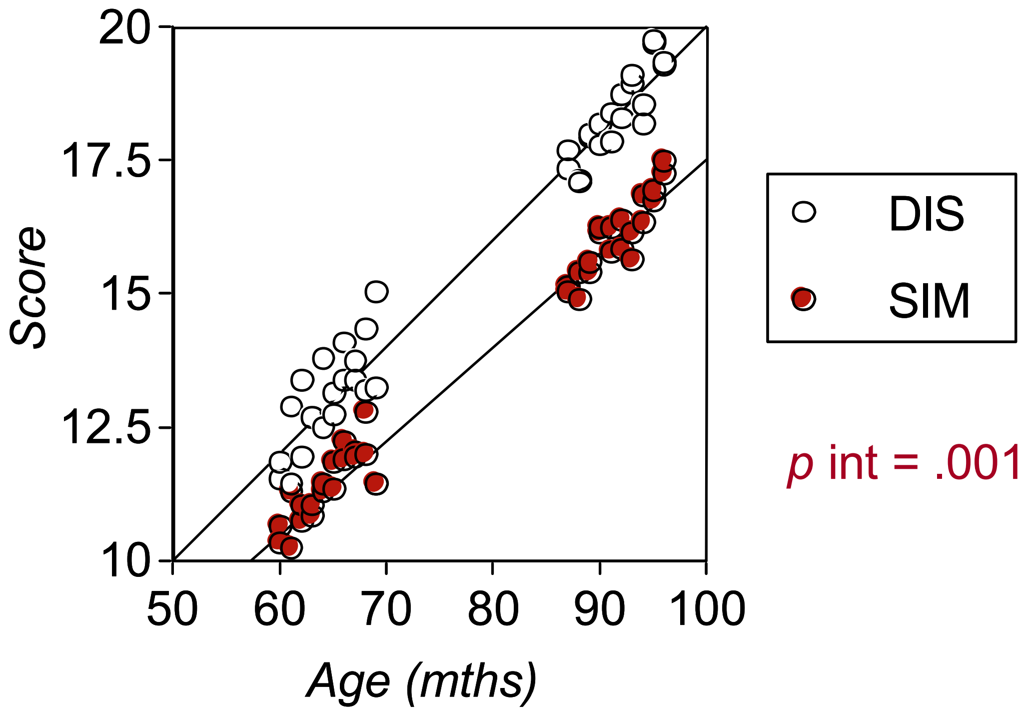
Presumably because the evidence suggests NULL effects in children younger than 7 (WLE with probed recall, speech-rate span associations, recoding of visually presented material)

But previous studies have tended not to employ large samples

In our WM study we see a measurable PSE for visually presented material among children younger than 7 – with n = 110 (partial η^2 = .12)

A qualitative developmental shift in rehearsal?

A truism – apparently qualitative changes can emerge from selective sampling of quantitatively developing data

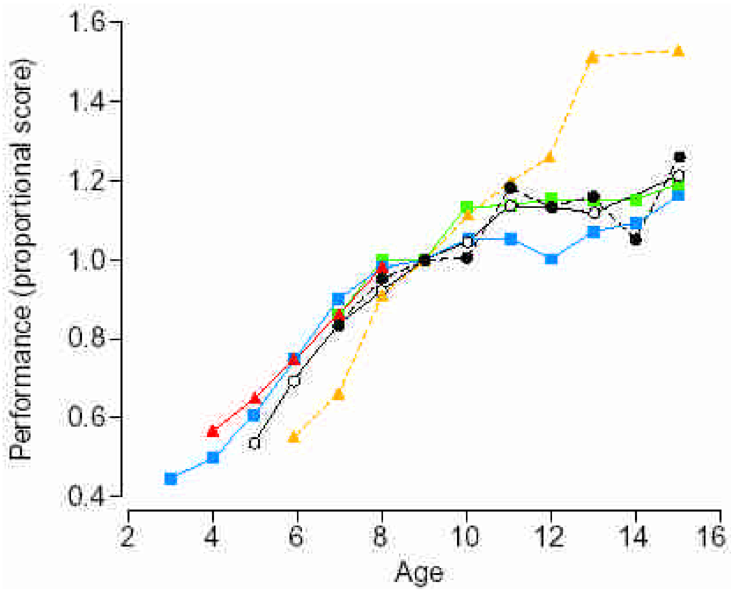


p int = .001

A qualitative developmental shift in rehearsal?

How can you tell the two possibilities apart (is this just an issue of semantics)?

Is there a step change in STM performance? This would be predicted if rehearsal *begins* around 7



Gathercole (1999)

Fig. 1. Performance on measures of short-term memory as a function of age. Mean performance of each age group is plotted as a proportion of mean performance of nine-year olds. Blue squares, digit span (phonological memory); red triangles, non-word repetition (phonological memory); open circles, forward digit span; green squares, Corsi blocks (visuospatial memory); yellow triangles, listening span (complex working memory); filled circles, backward digit span (complex working memory). All data are redrawn from

A qualitative developmental shift in rehearsal?

Regardless of the nature of the change, it appears that the extent of phonological rehearsal increases with age in childhood

This has implications for our understanding of what working memory span tasks measure:

A qualitative developmental shift in rehearsal?

In adults, and older (10 years + children): rehearsal essentially efficient – processing directly affects the efficiency of maintenance (cf. Barrouillet), and particularly demanding loads turn WM tasks into tests of retrieval from LTM (cf. Unsworth)

In young children (below 7 years): rehearsal either absent or of limited effect – WM tasks no different from STM tasks (Cowan et al., 2005)

A qualitative developmental shift in rehearsal?

In between (8 years / 9 years?) a phase in which the efficiency of rehearsal undergoes particular development – variation in WM task performance depends primarily on variation in rehearsal efficiency?

Even if rehearsal develops gradually, may get somewhat different outcomes in terms of what WM tasks measure in children of different ages

Alan Baddeley

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Nelson Cowan

Emma Dockerill

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Maura Sabatos

Helen Tam

David Williams

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Piaget quote in full

"It is customary to represent memory as a system of coding and decoding, which naturally assumes the intervention of a code. But curiously enough this code has been studied very little, as if it were taken for granted that the code stays the same throughout development … if one accepts our results concerning the operational development of thought, and if we thus admit the existence of a progressive structuring of reality by means of operations gradually constructed one after another or on the basis of one another, then the most likely hypothesis is that the memory code itself depends on the subject's operations, and that therefore the code is modified during development" (Piaget, 1968, pp. 1-2)

Us vs. Henry - simulations

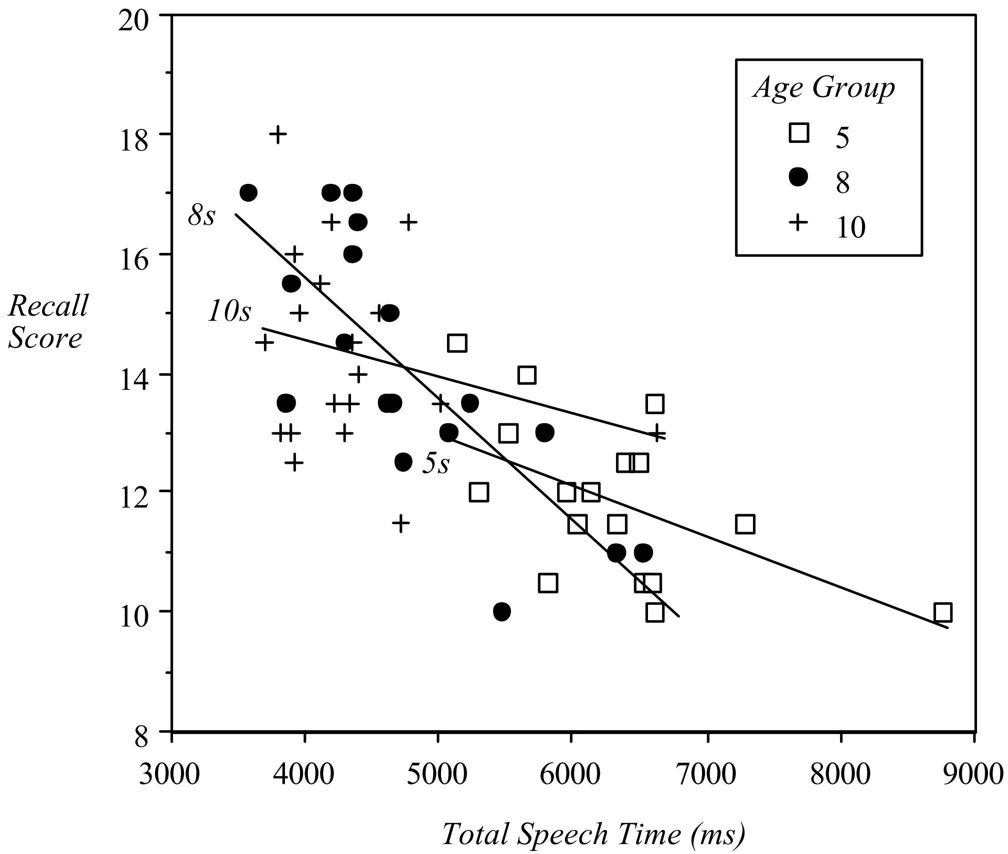
Our younger group do show a reliable (but reduced) PSE

But we used more trials than Henry per position

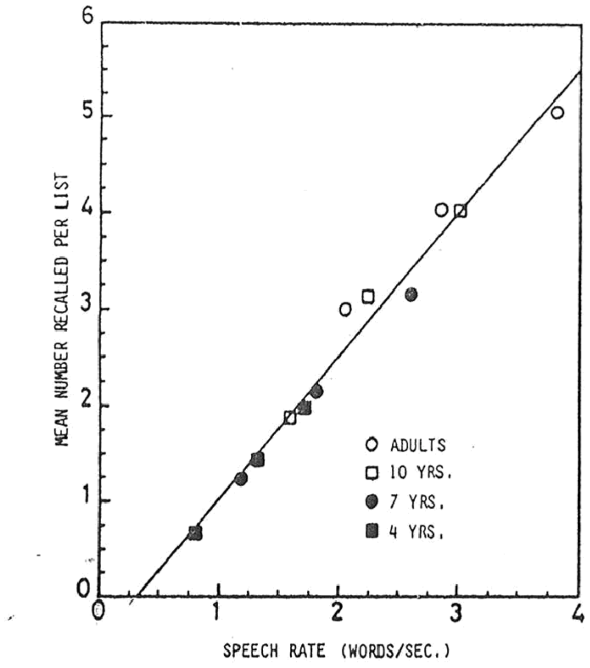
Simulating the chances of finding a null effect with fewer trials (1000 samples per simulation):

Trials	Proportion of effects non-significant
4	.10
3	.31
2	.52
1	.71

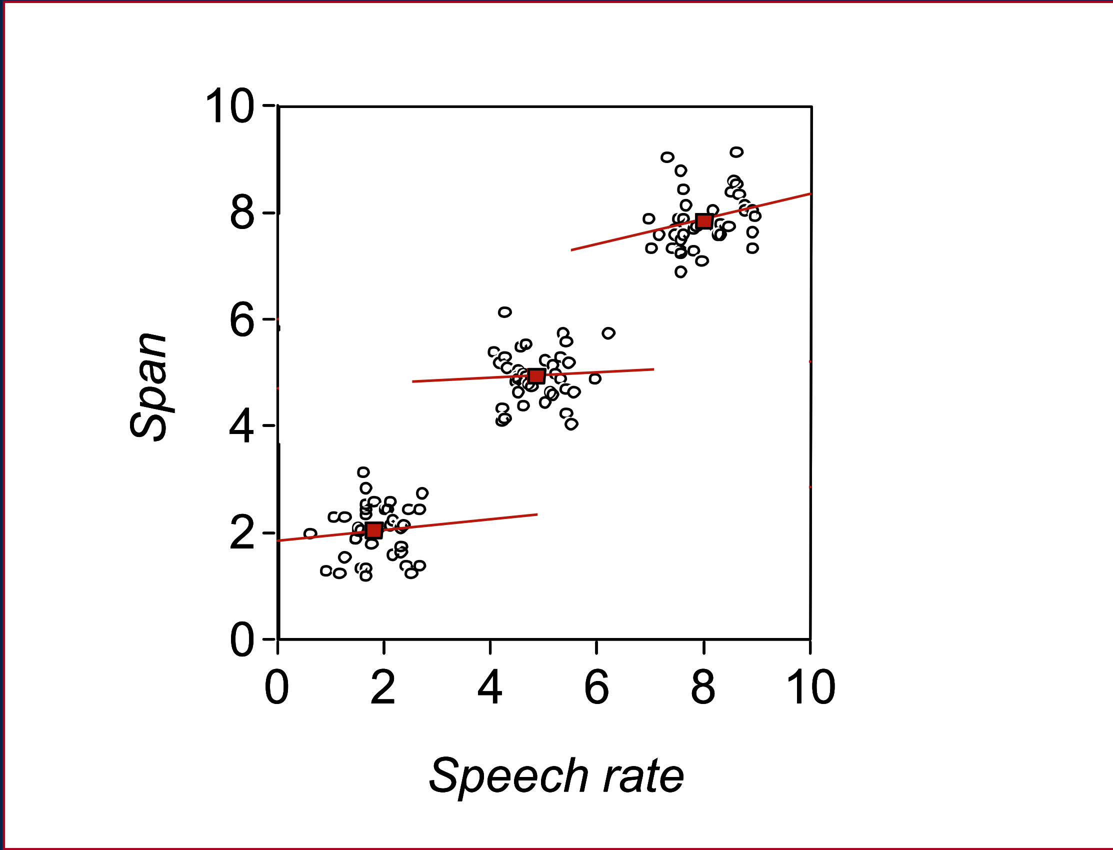
Jarrold et al. (2000b)



Hulme et al. (1984)



Ecological fallacy (Robinson, 1950)



See Cowan et al. (1994), Henry (1994)

Our hierarchical regressions

Change in r2 of the prediction of composite attainment:

Young group		Old group	
SS	.17	SS	.36
DS	.03	DS	.10
BP	.03	BP	.01
CS	.01	CS	<.01

A qualitative developmental shift in rehearsal?

Our recent data