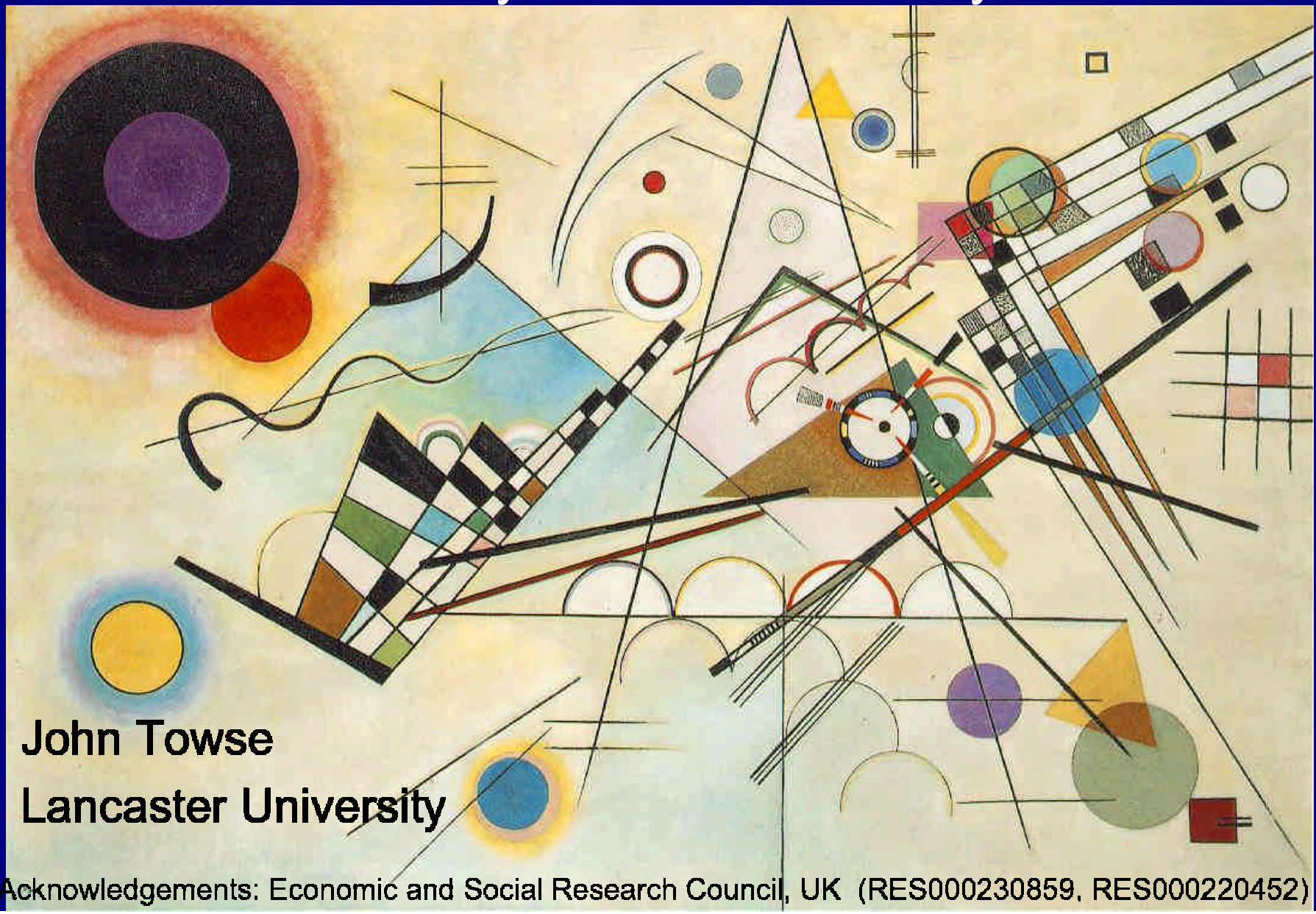
Development of working memory skills: insights from macro-analysis and micro-analysis



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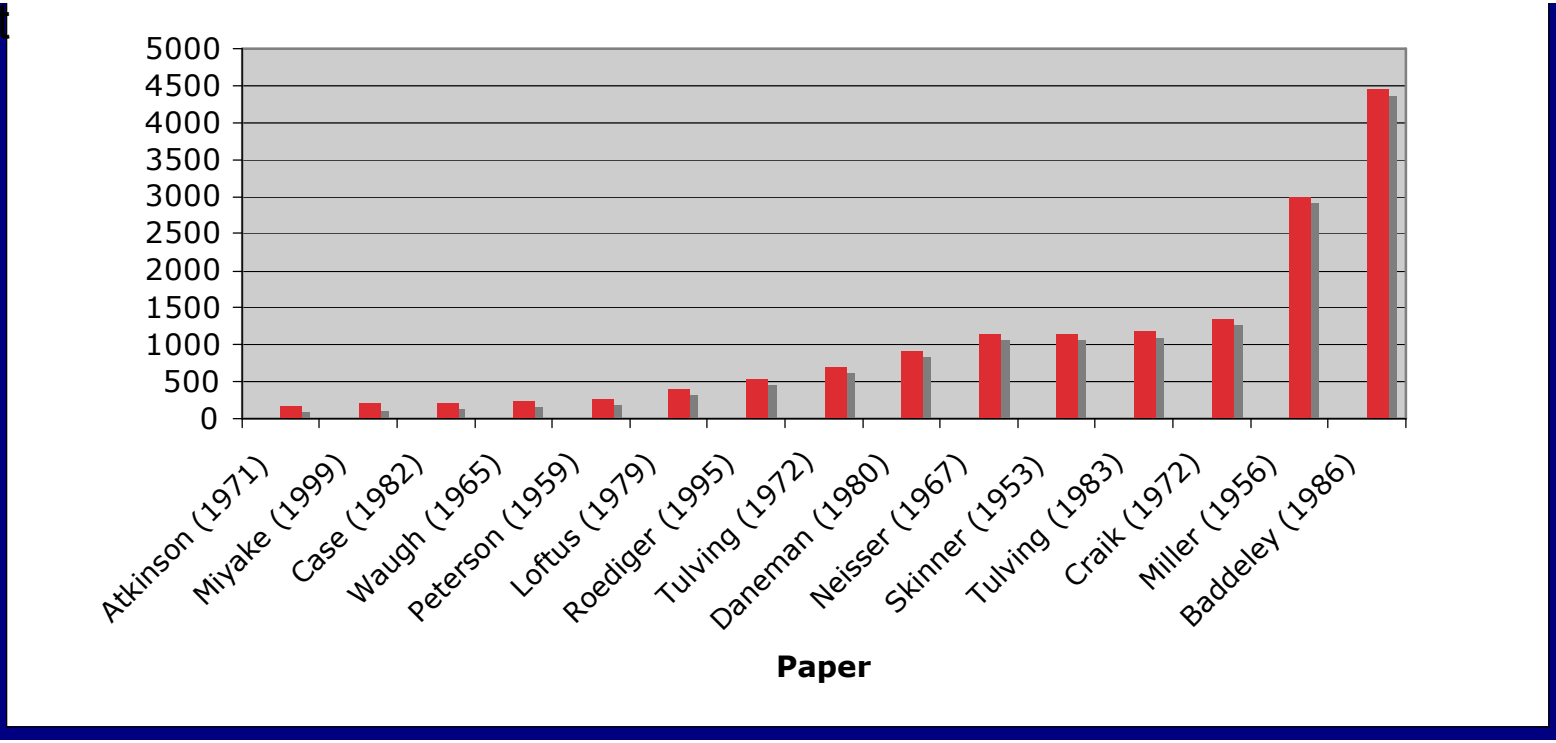
Overview

- Contemporary approaches to cognition
- The division between psychometric and experimental approaches
- A call for a symbiotic approach
- Appreciating the true complexity of explanatory constructs
  - The need for more elaborate theoretical models
  - The need for models of theoretical development

Overview

- Contemporary approaches to cognition

Saito & Towse (2007): Extent of citation popularity of the working memory concept



What types of theoretical debates are there?

- At the most general level, we can contrast two candidate frameworks for thinking about working memory:
  - A Piagetian concern with explaining developmental change and cognitive stability through just a few global parameters
  - A Broadbent-like information processing model that attempts to map out the architecture of cognition

What types of theoretical debates are there?

Piaget

- Macro-level
- Generic concepts
- Resonances with psychometric analyses
- Almost defined what it means to have a developmental theory

Broadbent

- Micro-level
- Identifies functional properties
- Convenient for experimental decomposition
- Helped to shape a “revolution” in cognitive science

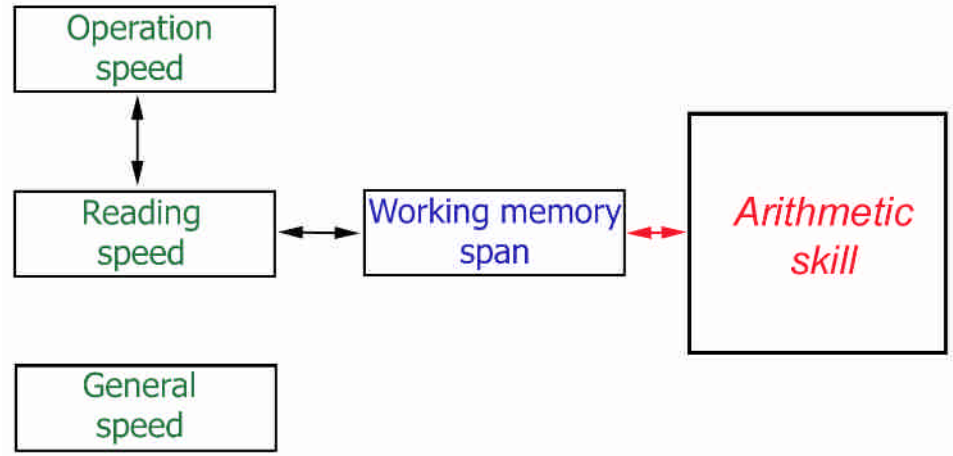
Macro-level variables underlying working memory capacity

- Processing speed
  - Links to changes with aging (Salthouse, 1992)
  - Lifespan changes in developmental cascade (Hale, Myerson & Lawrence, 2007)
  - Processing speed as an index of resource demand (Case, 1985)

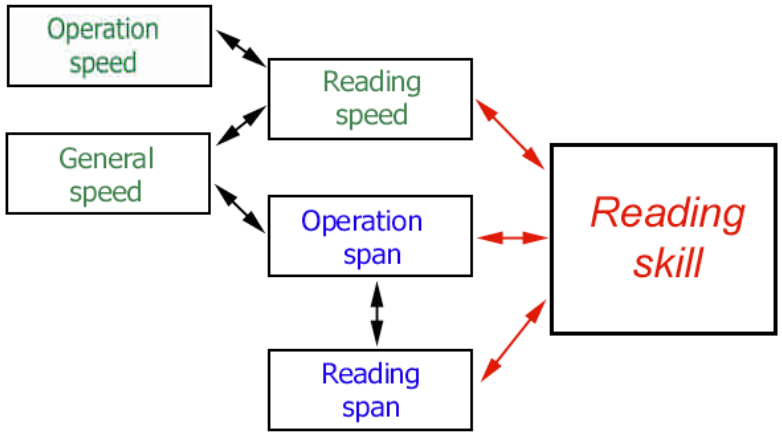
Unpacking processing speed as a construct

Predictions of scholastic skill

(data from Hitch, Towse & Hutton, 2001)



Hitch, G.J., Towse, J.N., & Hutton, U. "What Limits children's working memory span? Theoretical accounts and application for scholastic development." Journal of Experimental Psychology



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Unpacking processing speed as a construct

The single slope assumption

Case, Kurland & Goldberg, 1982

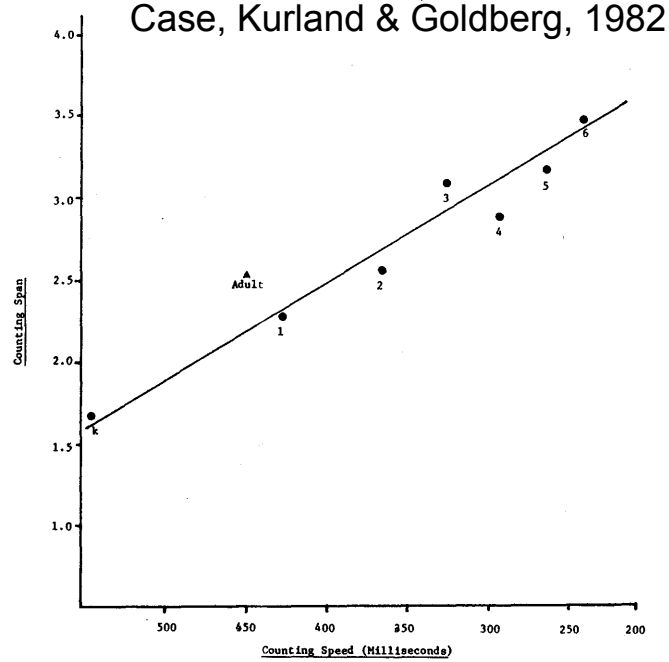
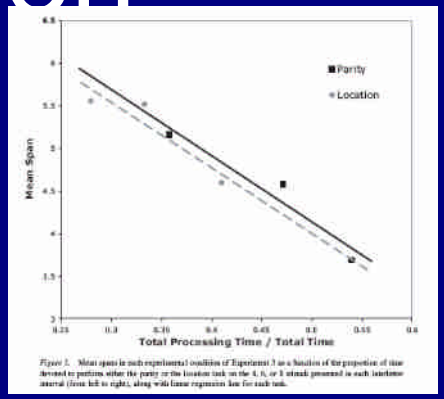
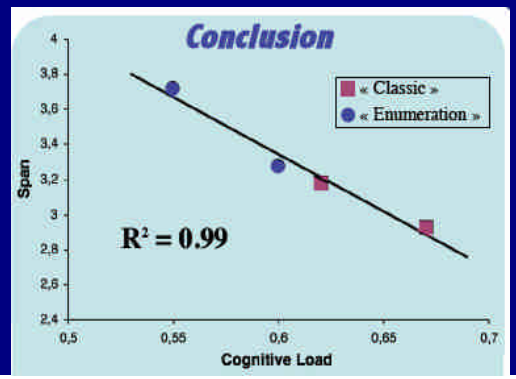


FIG. 2. Relationship between counting span and speed of counting at different age levels (Experiments 3 and 4).





Reading span data

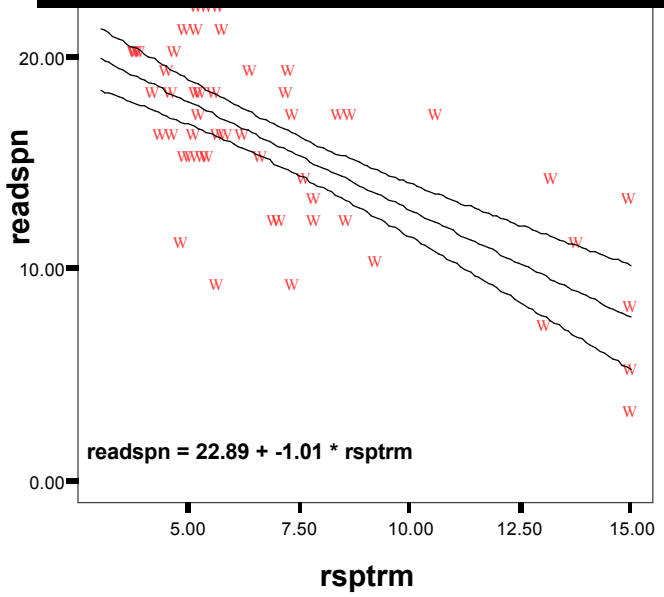
Towse, Hitch, Horton & Harvey (in prep)

- Two forms of reading span data differing only in whether recall items were part of the processing sentences
- Speed: span correlation overall: r(105)=-.540, p<.001, still sig after partialling out age

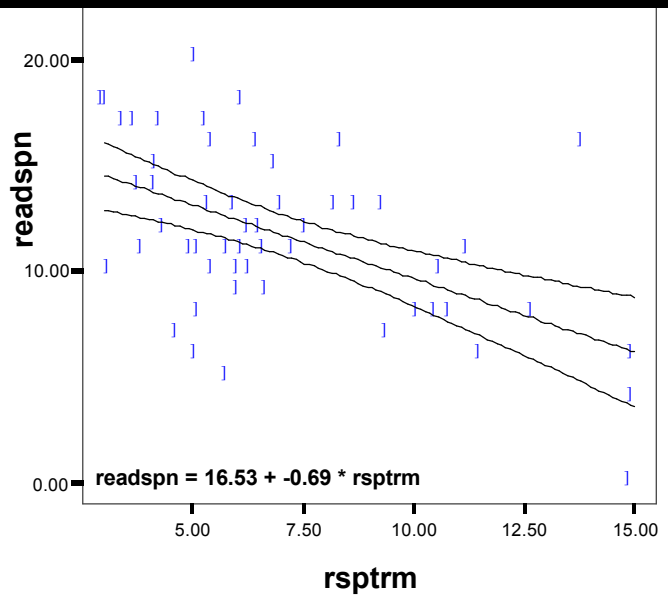
Words from sentence r(52)=-.734

Words unrelated to sentence r(48)=-.480

Chow test for equality of slopes: F(1,104)=7.63, p=.007

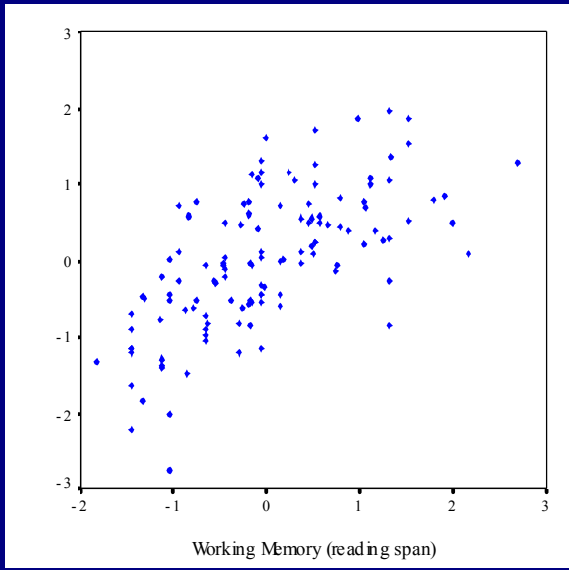


se correlations
ngth, z=2.08, p=

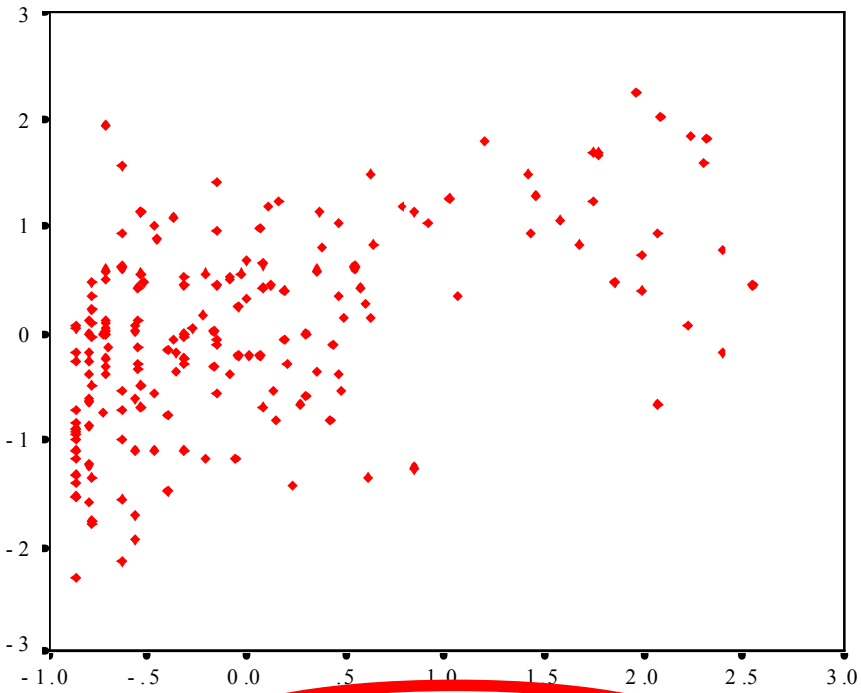


The predictive prowess of working memory:

Business as usual?

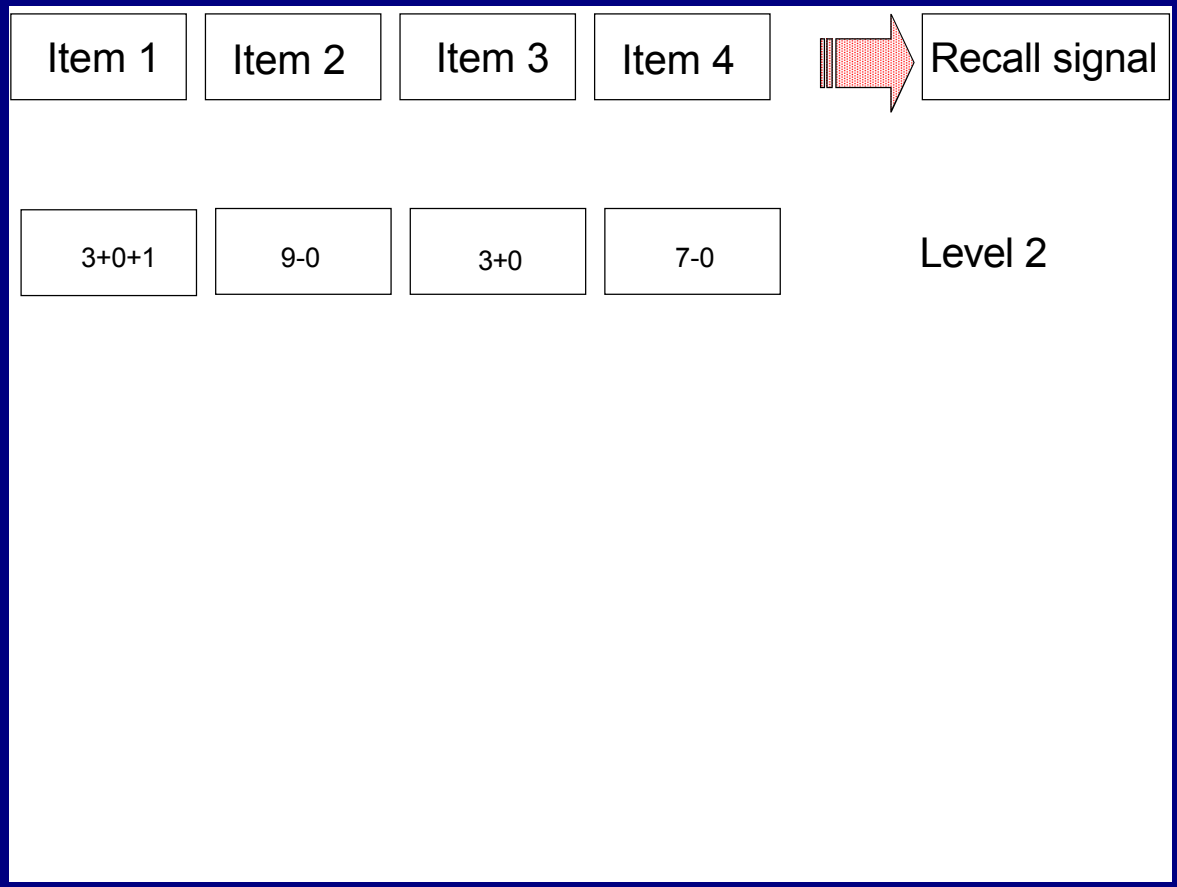


N=182, primary school children: Towse, Hitch et al. (unpub))



Working memory is not just about how much gets remembered, but also how persistent or long-lasting ‘memory traces’ are

An alternative to the emphasis on size -Working Memory period



Potential utility of working memory period

- As sequence length stays constant, one can ask various questions about memory, for example:

- Does each sequence item contribute to the predictive outcome of working memory?

- Does the duration of individual processing events in the sequence matter for overall performance?

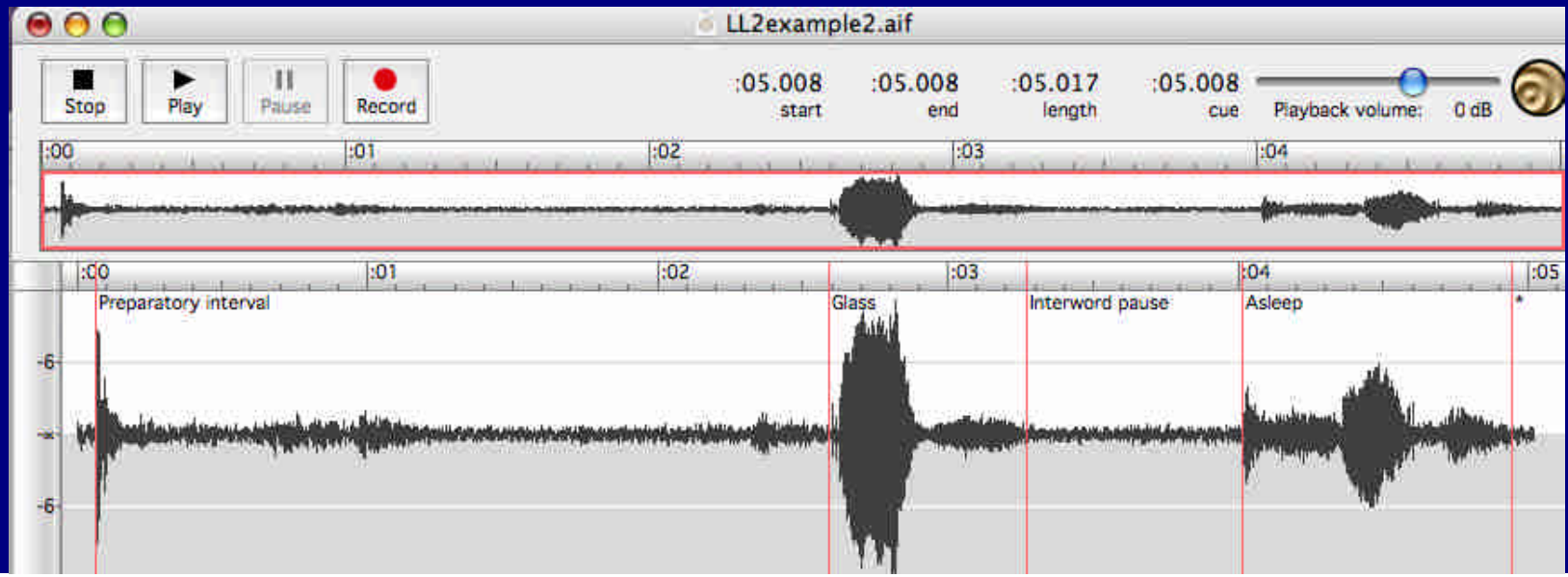
- Is recall affected by the build up of proactive interference (PI) using items from repeated categories?

Unpacking processing speed as a construct

- Arguments so far
  - Processing speed can be a useful global cognitive parameter
  - Yet processing speed can play different roles in explaining children's scholastic skills and development
  - The relationship between speed and span is potentially subtle and variable
  - There is merit in weaving processing time into the very fabric of memory measurements
- Processing speed can mean different things depending on the point of interest in the task…

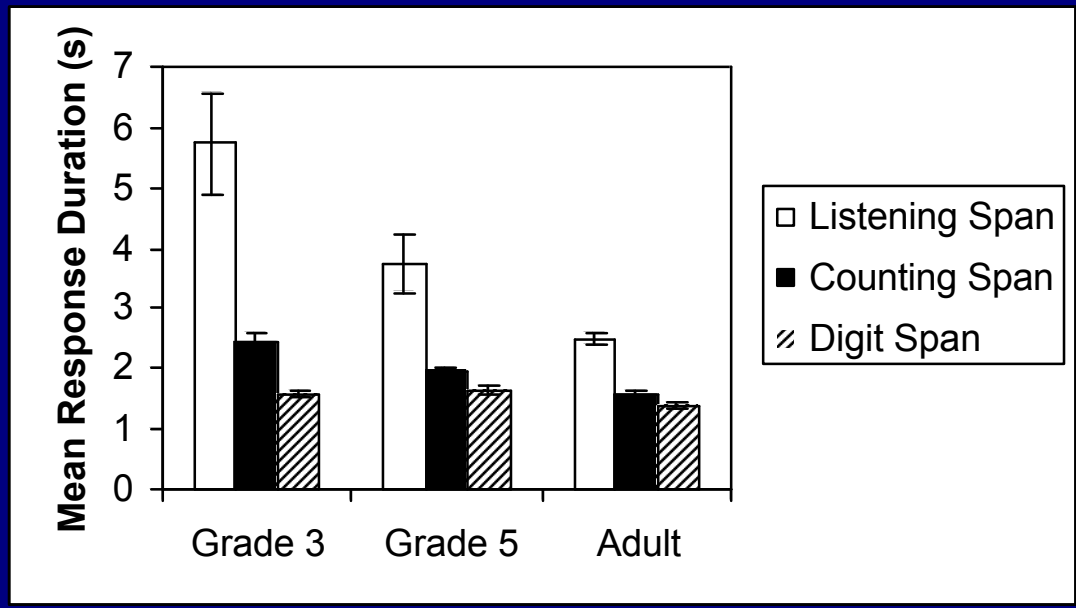
Example of reading span trial

- Recall isn't instantaneous
- Recall can be segmented into separate, contiguous elements
  - The gap before recall actually starts
  - The sequence words
  - The interword pauses



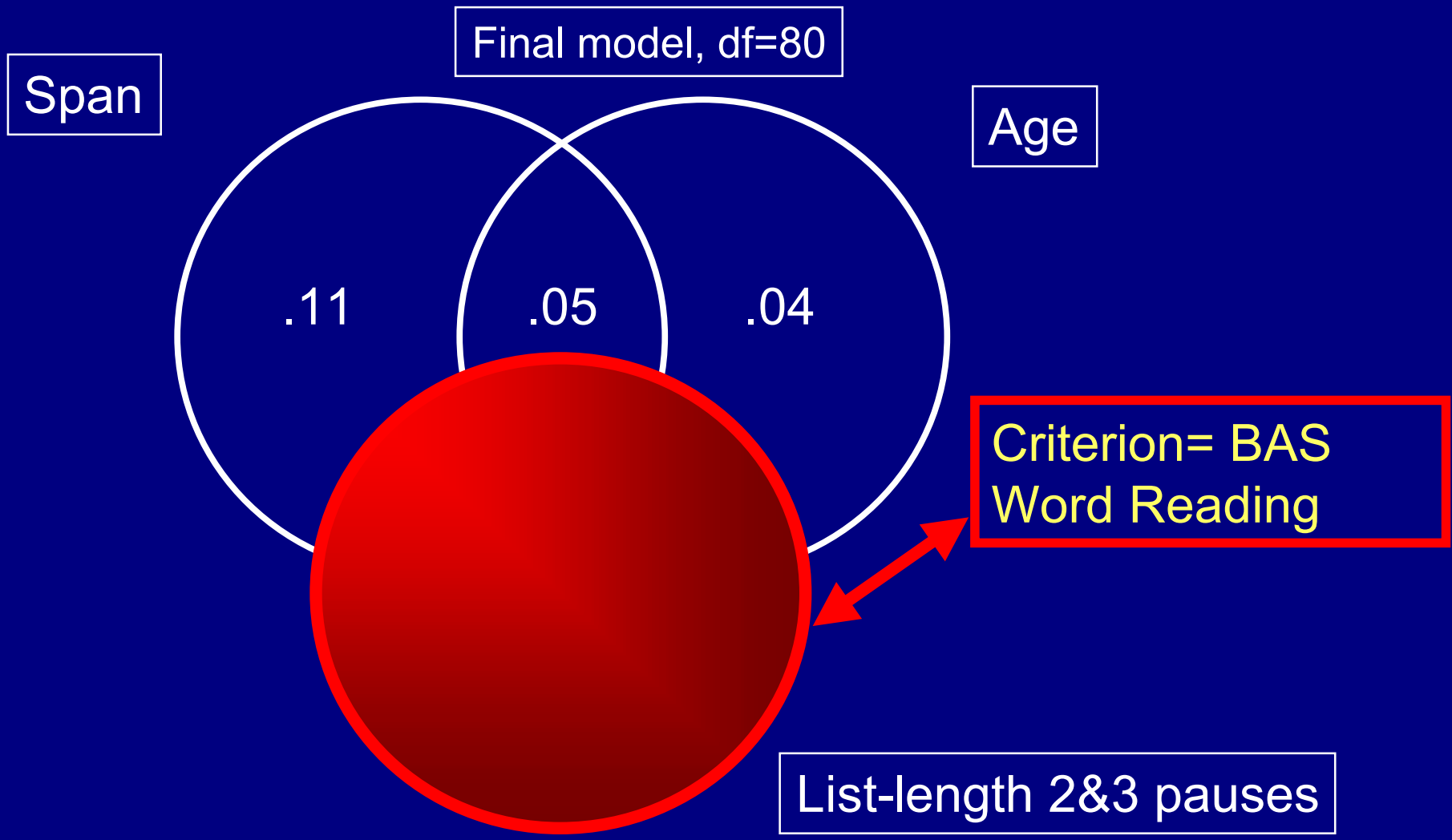
Recall timing in WM: data and theory

- Cowan, Towse, Hamilton, Saults, Elliott, Lacey, Moreno & Hitch (2003)
  - Length of recall episodes in reading span
  - Differences across tasks



Individual differences in recall timing

(re-analysed data from Towse, Cowan, Horton & Whytock, *Developmental Psychology*, 2008)



Macro-level variables underlying working memory capacity

- Processing speed

Macro-level variables underlying working memory capacity

- Processing speed
- Memory strength

Recall reconstruction hypothesis

(Towse, Cowan, Hitch, & Horton, *Experimental Psychology*, in press)

- Previous work shows that there are long pauses in reading span recall.
- The recall reconstruction hypothesis suggests some reasons why:

- *Participants may arrive at recall with several representations, including some from processing*

- *The output sequence is not always fully formed at the onset of a recall cue. The items themselves may not be complete*

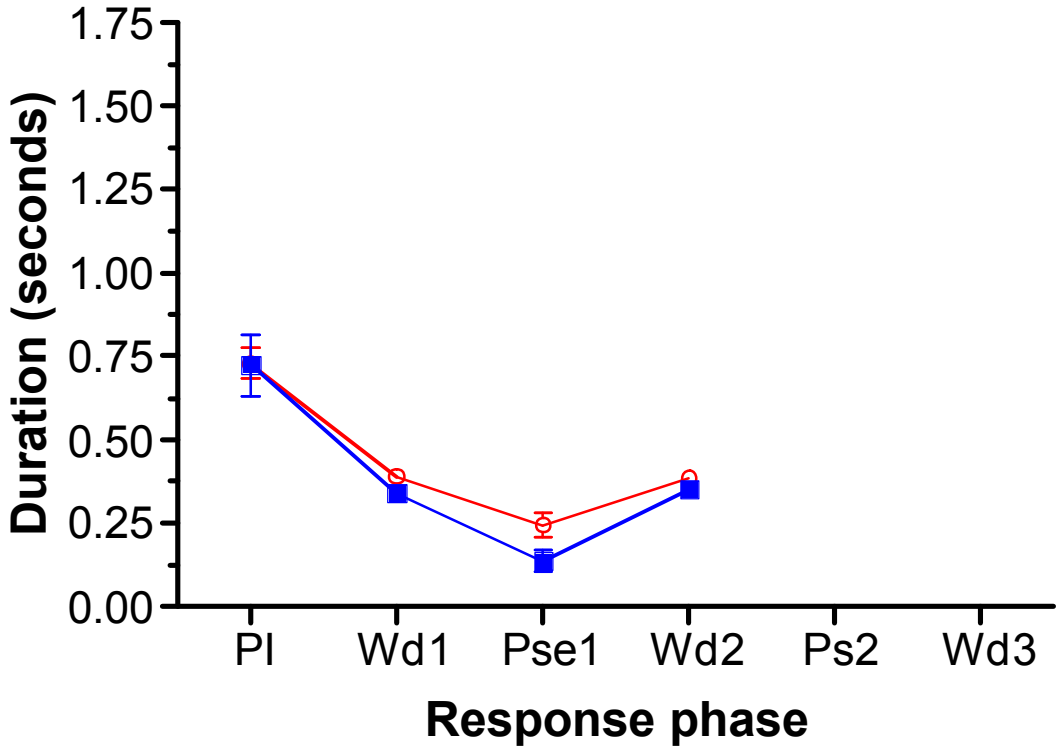
- *Thus recall is not just a retrieval act, but a constructive one too*

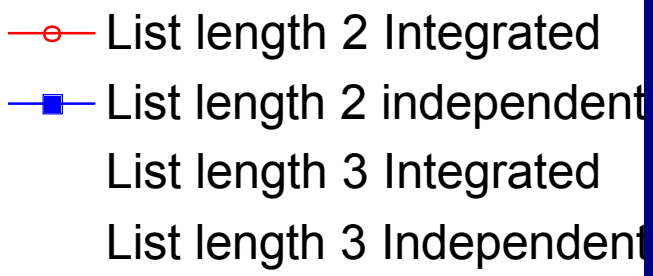
Recall reconstruction hypothesis

(Towse, Cowan, Hitch, & Horton, *Experimental Psychology*, in press)

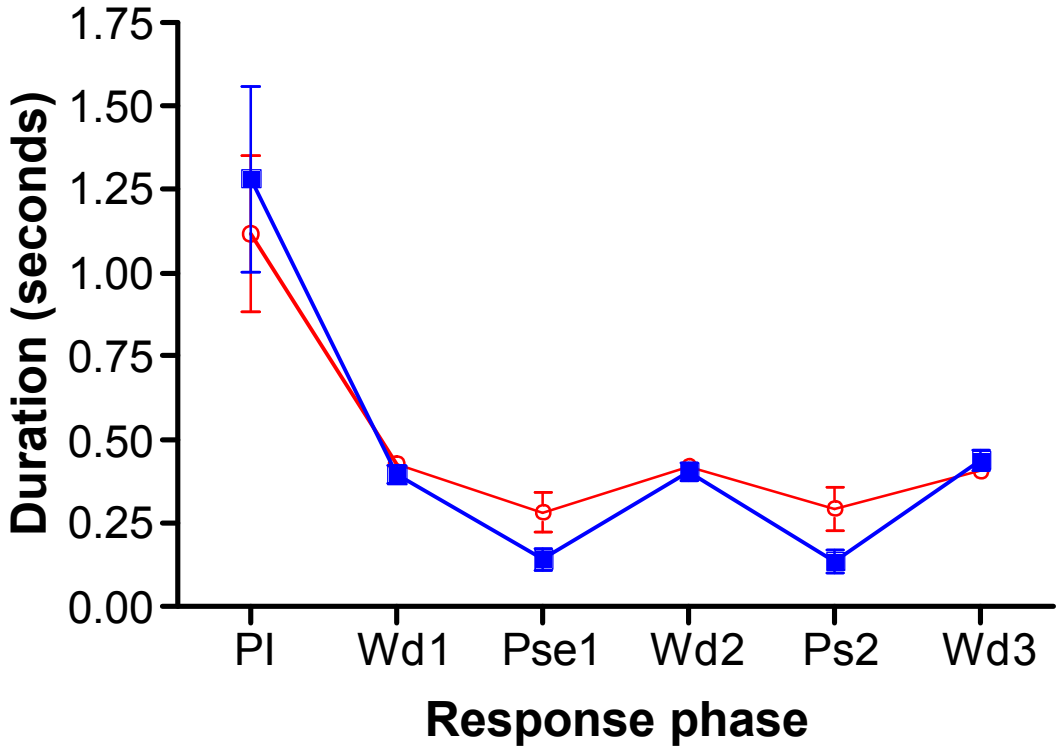
- Four experiments with broadly consistent outcomes
- Experiment 1:
- Recall span task administered to 24 adults
  - Read a sentence and remember the completion word
    - The rocket went into outer space. [space]
    - Referred to as the integrated condition
  - Read a sentence and remember an unconnected word that follows
    - The rocket went into outer space. [bridge]
    - Referred to as the independent condition

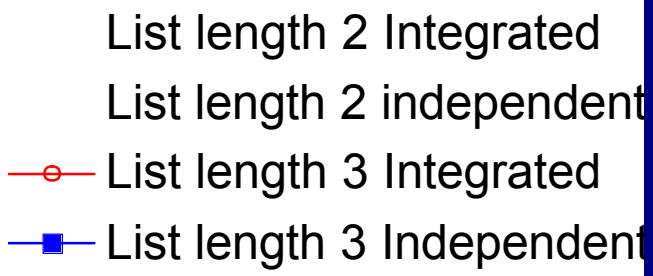
The profile of recall timing





The profile of recall timing

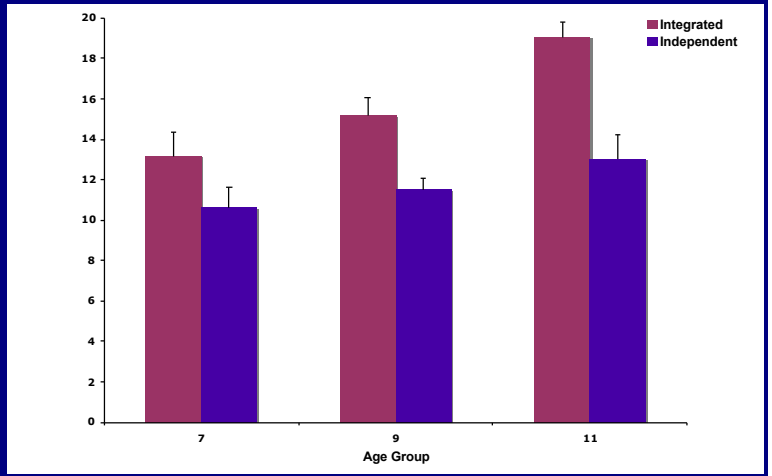




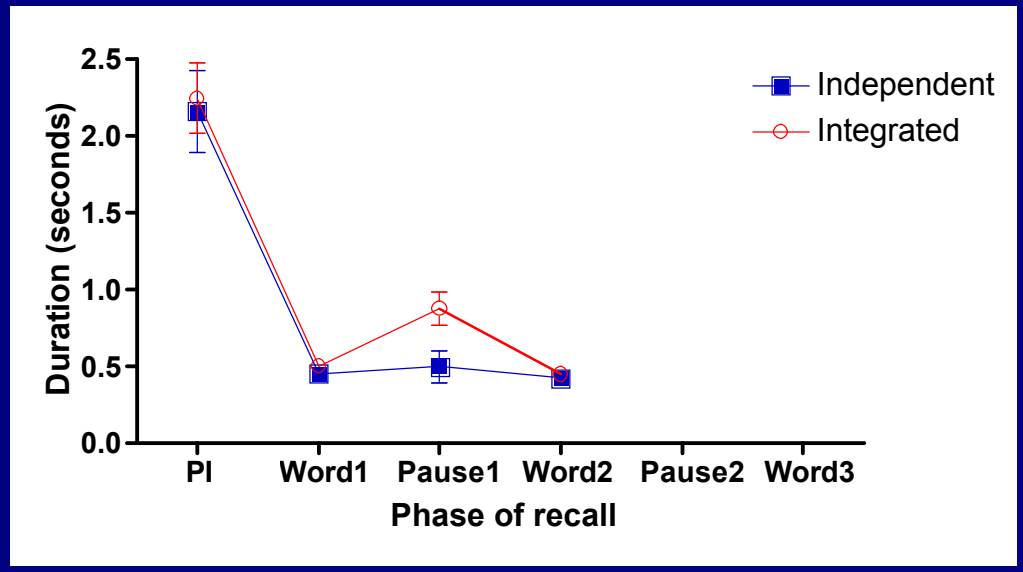
Developmental data relevant to recall reconstruction

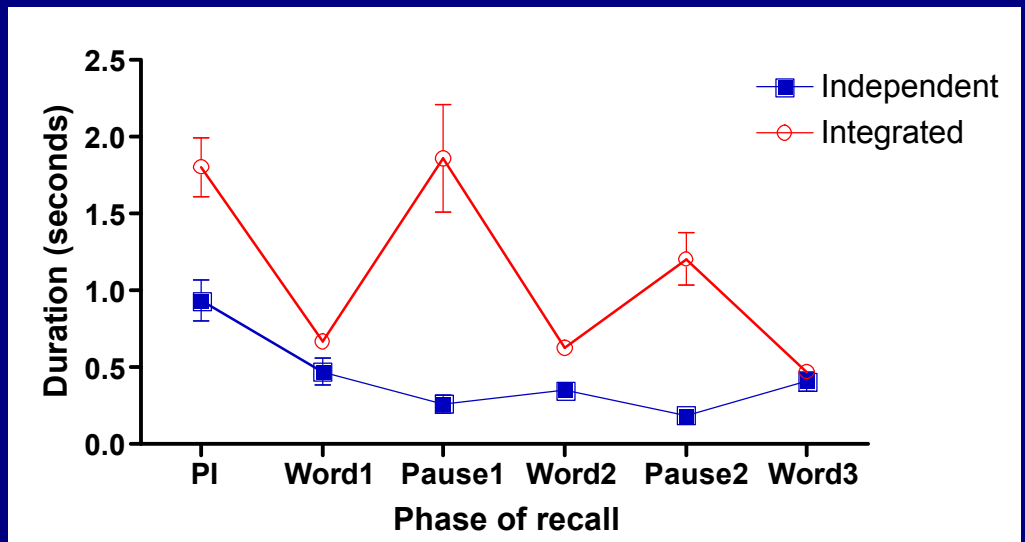
- Towse, Hitch, Horton & Harvey (unpublished)
- N=108 children, ages 7, 9, and 11 years

Age: $F(2, 101)=11.1$, $p<.001$, $h_p^2=.180$
Task: $F(1, 101)=28.2$, $p<.001$, $h_p^2=.218$
Interaction, $F(2,98)=1.61$, $h_p^2=.031$



Recall timing among children





The recall reconstruction hypothesis

- With integrated sentences, participants can draw upon sentence information for recall.
  - This facilitates recall accuracy
  - This is responsible for longer pauses in recall
  - Processing time dissociates at recall
- As a corollary…
  - Do some sentences scaffold recall better than other sentences in the integrated condition?

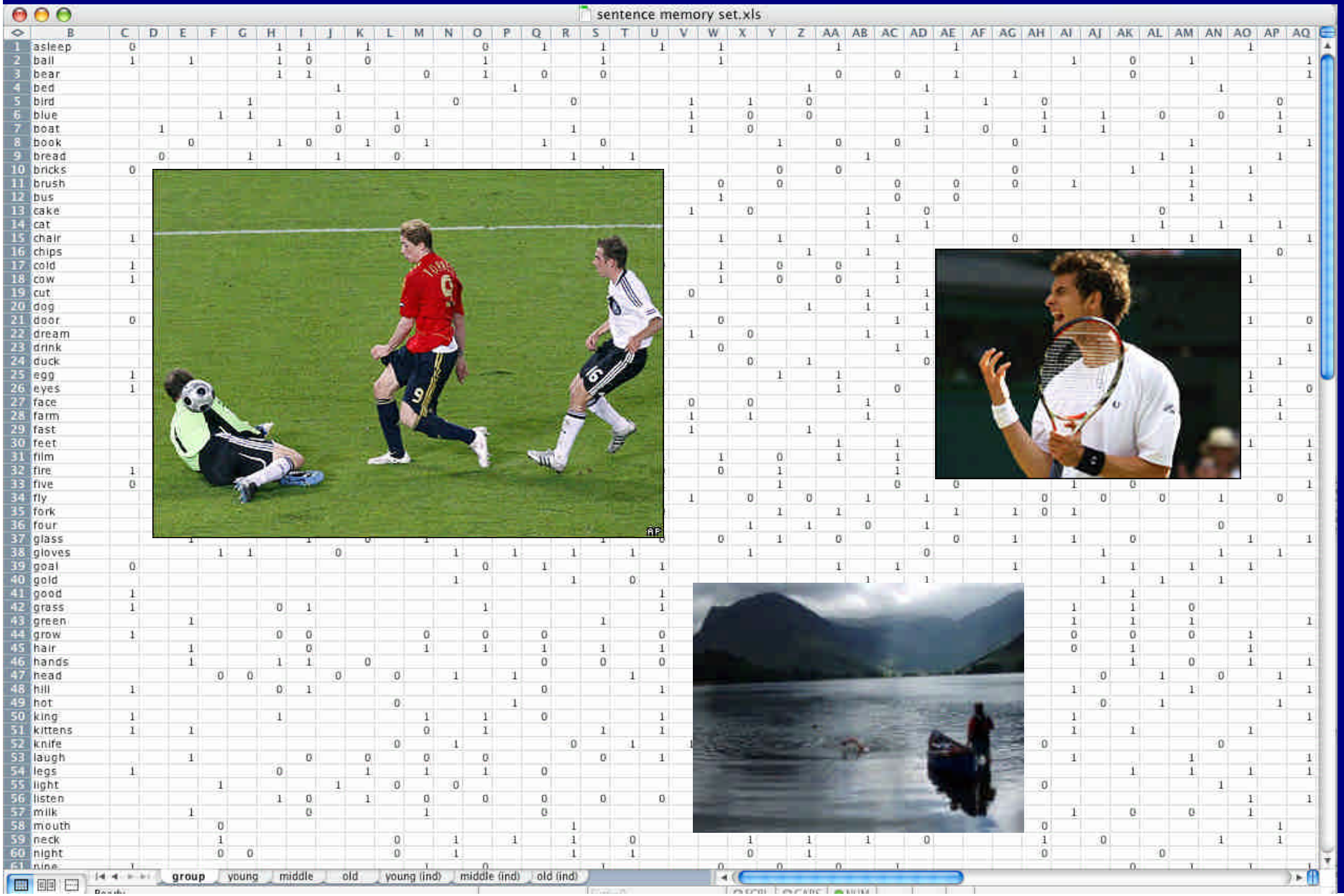
Recall reconstruction - sentence variance

- For every sentence/memorandum presentation, recorded whether subsequent recall was correct or not
- One can build up a profile of recall proportions for each of 88 sentences across all 54 participants
  - (ie item rather than subject analysis)

Why this won't work…

- Most recall variance will be attributable to
  - Sequence length
  - Serial position
  - Processing speed
  - Proactive interference
  - Specific intra-list combinations
  - Transient factors (e.g. distraction)
  - Etc.
- The sentence corpus was not developed to investigate variance in memorability
- Each child is presented with only a subset of the corpus, decreasing power
- The logic of reconstructive processes doesn't necessitate meaningful variance in sentence memorability

A lost cause


sentence memory set.xls
group
young
middle
old
young (ind)
middle (ind)
old (ind)

Recall reconstruction - sentence variance

- Some sentences were followed by correct recall more often than others
  - Some sentences with correct recall >.9
  - Some sentences with correct recall <.4
- But is this just random variance?

Recall reconstruction - sentence variance

- Carry out the same sentence analysis procedure on dataset reported in Towse et al. (2008) with integrated sentence type
  - Use ascending sequence length administration
  - Use first session data
  - Sequence length 2, 3, 4, & 5 where available.
- Different children, non-identical ages and non-identical procedure
  - Yet, recall proportions for the 88 sentences correlated in these two datasets, r=.21
- Despite all the reasons for the analysis to not work, there is consistency!

Recall reconstruction - sentence variance

- So consistency or reliability *has* been established in "recallability" of integrated material
- We have argued that recall reconstruction isn't possible -in the same way- in the independent condition because the sentence/memorandum combination is different.
- Therefore, what happens to the recall proportions among the 54 children in the independent condition?
  - No correlation with the integrated condition, r=.04

		Towse et al. 08	Independent	Words
Weak recall	.397	.564	.456	.489
Strong recall	.897	.672	.516	.528

Recall reconstruction -
Conclusions and implications

- Convergent evidence for reconstructive processes in complex span configurations
- Complex spans are not (just) dual task paradigms
- Macro-level, individual difference analysis (demonstrating recall pauses are predictive of span and ability) can be unpacked and complemented with micro-level experiments and item-level analysis.

Macro-level variables underlying working memory capacity

- Processing speed
- Memory strength

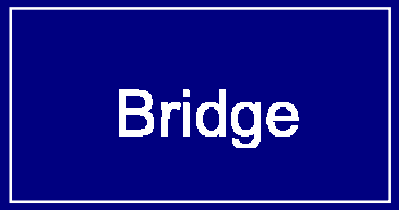
The graded nature of recall representations:

Towse, Hitch, Hamilton & Pirrie (in press)

- We tend to envisage that a memory is either available or inaccessible

or

But should we think about it as



ie, graded in nature (Munakata, Morton & O'Reilly, 2007)

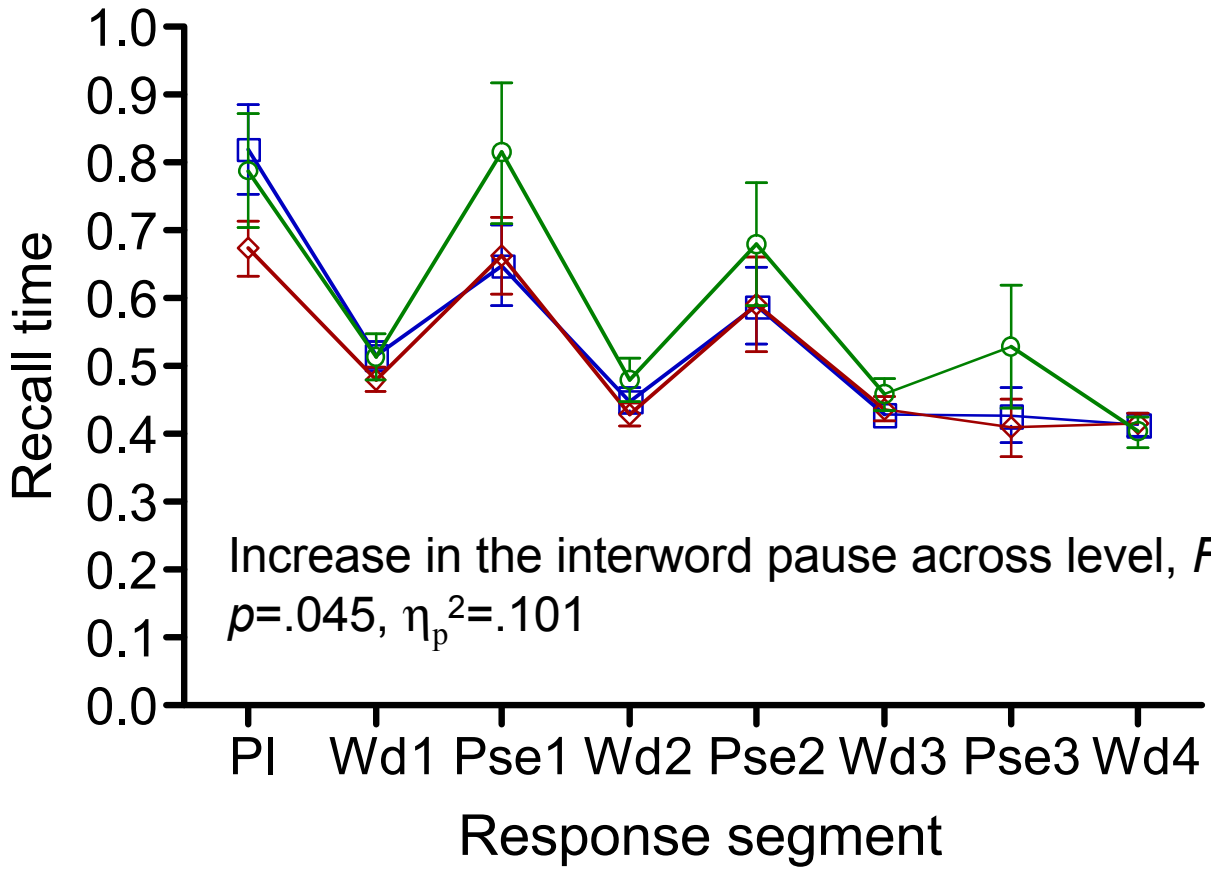
The graded nature of recall representations:

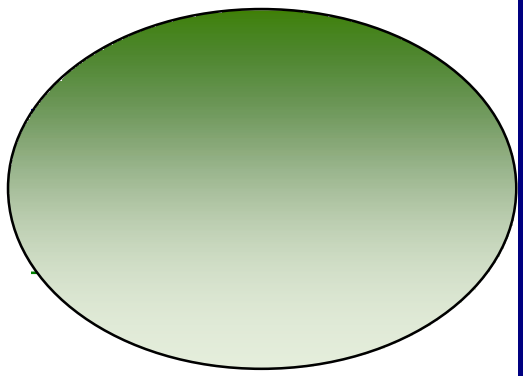
Towse, Hitch, Hamilton & Pirrie (in press)

- Investigating the demands in producing the correct answer
  - In the period task, the sequence length remains constant
  - But the retention characteristics do not

- Analysis of correct recall from 47 8-year-olds given a 4-event operation period task
  - Began with sums such as “6 + 0 =”
  - Later given sums such as “5 + 1 =”
  - And still later sums such as “4 + 1 + 1 =”

Stretching the endurance of memory





Increase in the interword pause across level, $F(2,58)=3.27$, $p=.045$, $\eta_p^2=.101$

Macro-level variables underlying working memory capacity

- Processing speed
- Memory strength

Macro-level variables underlying working memory capacity

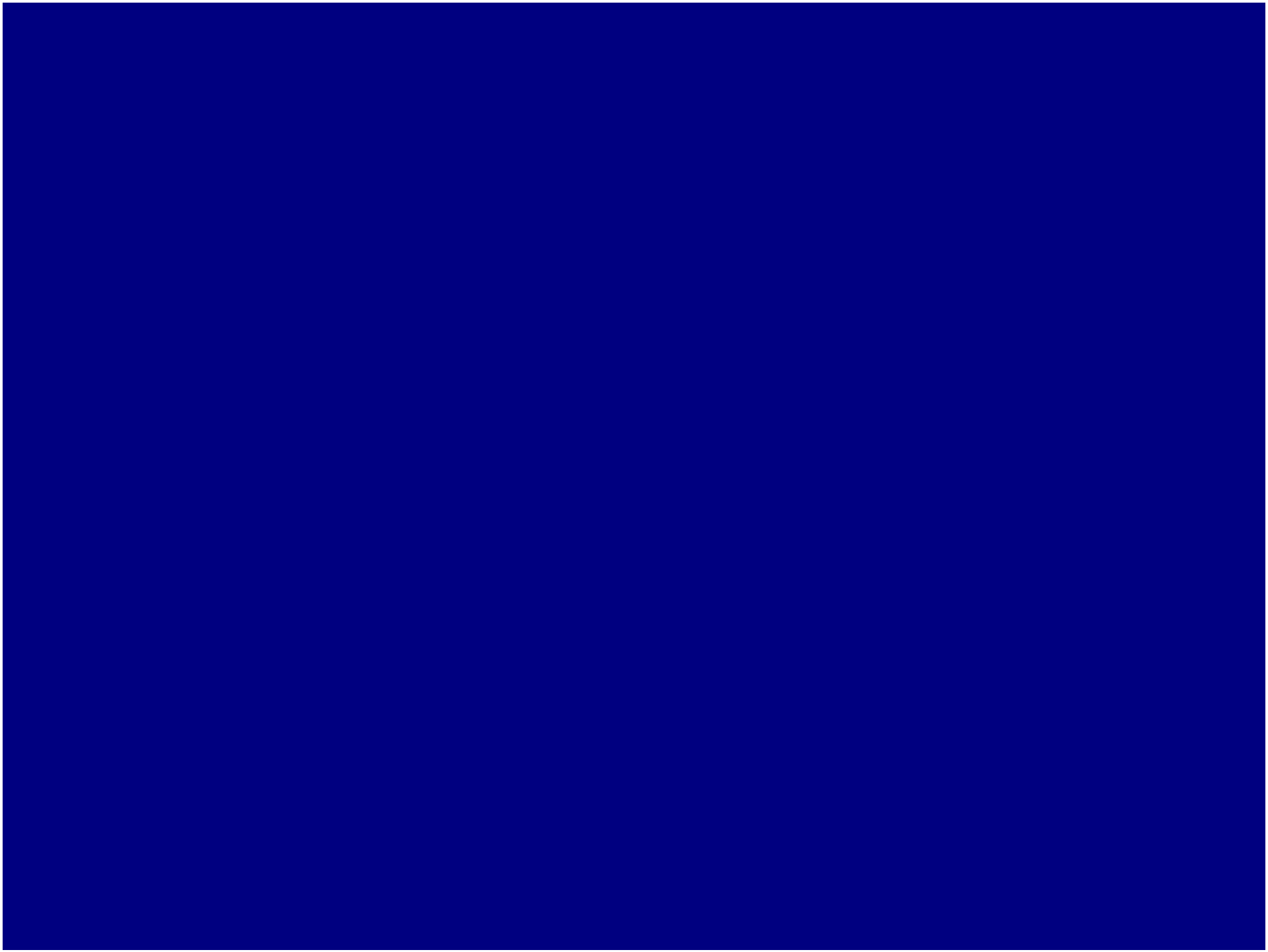
- Processing speed
- Memory strength
- Executive attention

Unpacking executive attention

- Working memory span isn't just a primary task / secondary task environment
- Complex span paradigms can incorporate emergent properties (Towse & Houston-Price, 2001)
- Task decomposition can help refine what these emergent properties are
  - Bayliss, Jarrold, Gunn & Baddeley (2003)
  - Jarrold & Bayliss (2007)
- Once again, there's more to the dimension than initially meets the eye

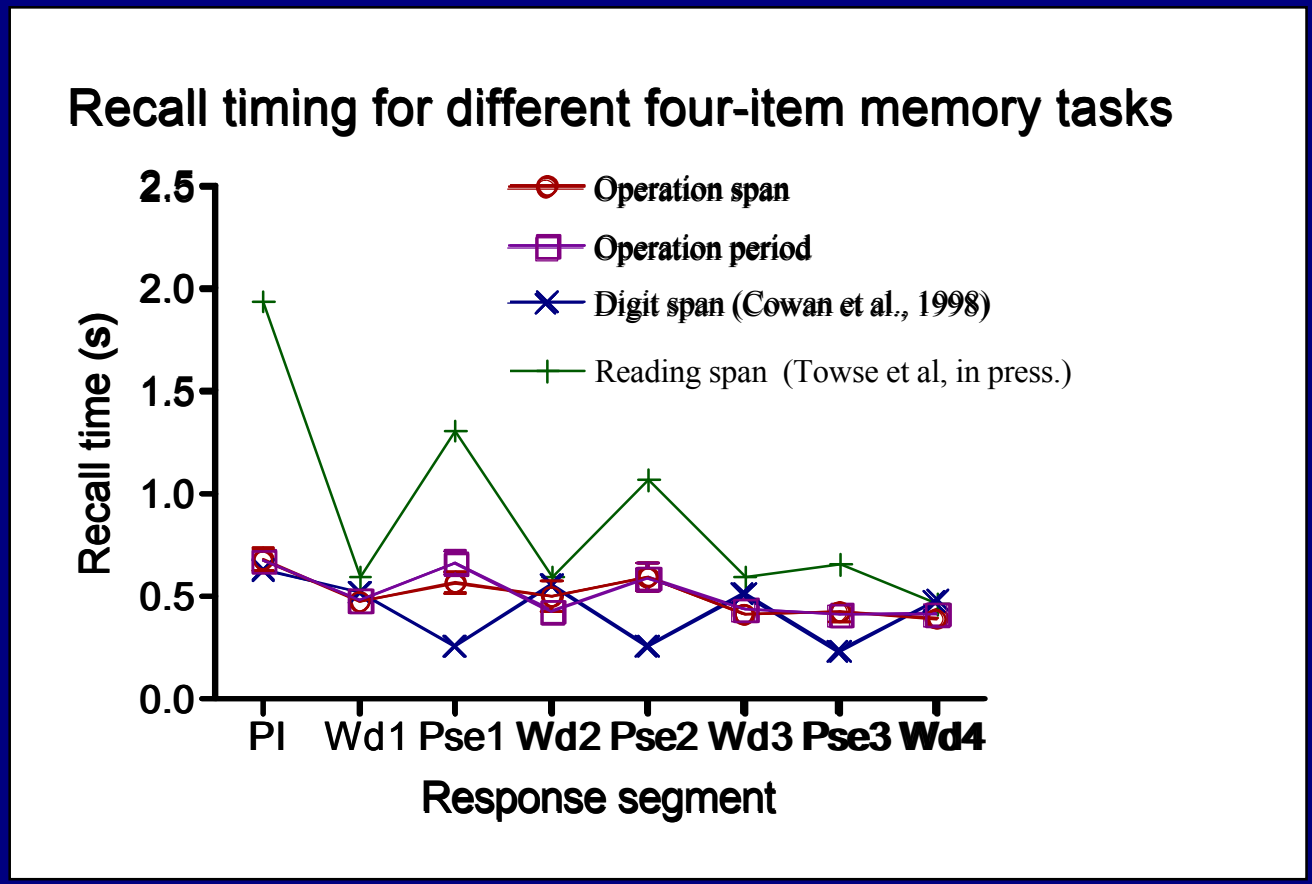
Conclusions

- The value of convergent operations in working memory research
  - Macro and micro-level approaches
  - Potentially complementary perspectives from adults and children
- The richness of the working memory construct
  - We can go beyond simple, global, explanations
- The importance of understanding developmental mechanisms.



Metaphors for memory?

- The Suitcase metaphor
  - Size limits functionality
  - Some have bigger suitcases than others.
  - More items can be packed into a suitcase when the items are small.
  - Inefficient packing means that fewer items fit in the suitcase.
- One ought to measure suitcase size.

- The vacuum flask metaphor
  - Memories are perishable.
  - An important characteristic is how well memory traces are insulated against loss.
  - ...And how long they are left to degrade.
  - Size is not the (only) important dimension.
- One ought to measure endurance.

Comparison of tasks