Working Memory Mechanisms & Complex Span in Typically Developing Children

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Background

Working Memory = ability to engage in simultaneous information processing and storage, i.e., ability to store information while processing that or other information

(Baddeley & Hitch, 1974; Engle, Kane & Tuholski, 1999; Cowan et al., 2005)
• Importance of Working Memory: It is predictive of higher level cognitive abilities (fluid IQ, reading and spoken language comprehension, math)

• Working Memory is measured using various kinds of complex memory span tasks

(Baddeley, 2003; Engle, Kane & Tuholski, 1999; Gathercole, 1999; Lepine, Barrouillet & Camos, 2005)
Measurement of WM

(Daneman & Carpenter, 1980; Case, Kurland & Goldberg, 1982)

• **Listening span**
  Listen to sets of sentences (2 to 7 sentences in a set). Task is to:
  (a) Processing: respond to truth value after each sentence (Y/N)
  (b) Storage: recall the last word of each sentence at end of the entire set

• **Counting span**
  Processing: Counting # of dots on a series of cards
  Storage: Remember the count from each card
  Range of counts vary from 2 counts to 7 counts
Recent Developmental Memory Research: 3 Mechanisms of WM

- STM storage
- Processing Speed
- Attentional Resource Allocation

Working Memory
Need for the Study

- Mechanisms of STM storage and processing speed have been evaluated as separate abilities underlying complex memory span across different studies
  - Processing Speed has been investigated in terms of: (a) general processing speed independent of the WM task itself AND (b) the speed with which the processing component of the WM task is performed
- Few studies have examined how these mechanisms differentially affect complex span in the same study
- Attentional abilities have not yet been explicitly examined along with STM and processing
Bayliss et al. (2005) only study to examine individual and collective influences of STM and processing speed on children’s complex memory span

Present Study

- Replication of Bayliss et al.: Examine STM and Speed
- Extension of Bayliss et al. Examine Attentional Allocation
Purpose

1) Examine the relation among the memory abilities STM, processing speed and attentional allocation) and age in young school-age children

2) Examine the individual and collection influence of these three memory abilities on children’s complex memory (listening) span
Method

- **Participants**: 65 typically developing children (32 boys, 33 girls)
  - Age range = 6-12:6 yrs \((M=8:6; SD=1.8)\)
  - Native English-speaking children
  - Normal-range hearing
  - Normal-range Nonverbal IQ (TONI-3)
  - Normal-range Language (CELF-4, TROG-2, PPVT-3)
  - Normal-range Speech (Goldman-Fristoe 2)
Experimental tasks

**STM Storage** - Digit span task

**Speed** - Simple auditory visual reaction time task

**Attentional resource allocation** - Woodcock-Johnson 3: Auditory working memory subtest

**Complex working memory** - Listening span task

(Computerized administration using E-prime, over multiple sessions)
Digit span task (STM storage)  
(List length 2-7)

Stimulus: 9, 2, 5  
Response: 9, 2, 5

Dependent Variable: Longest list length recalled accurately on 2 of 3 trials

Stop Rule: Miss 2 of 3 trials on two consecutive list lengths
WJ-3: Auditory working memory subtest (Attentional Resource Allocation) (List length 2-7 verbal items)

Stimulus: 2 cat 4 Response:

Dependent Variable: Longest list length recalled accurately on 2 of 3 trials
Auditory visual RT (Basic processing speed)
E.g., Stimulus: “Blue”
Response: Touch correct color as fast as possible

Dependent Variable: Smoothed mean RT (ms)
Listening span (Complex memory span)

Stimuli: 20 simple sentences, controlled for length, word familiarity, monosyllabic final words (equal number of nouns, adjectives and verbs)
Sample 4-sentence set

The teacher threw the books to the floor  
Y  N

The tiger sat on the grass that was red  
Y  N

On Saturday mornings the lady loves to bake  
Y  N

The girl called her mom on her dress  
Y  N

Processing Component: Respond to truth value of sentence
Procedure

Child listened to sentences (2- to 6-sentence sets)
- Answered Y/N (touched screen) after each sentence (approximately equal #s of Yes and No responses)
- At end of each sentence set, recalled as many sentence final words as possible (in any order)

Dependent Variable: Percent total words recalled
### Summary of Descriptive Statistics for all measures (N=65)

<table>
<thead>
<tr>
<th></th>
<th>Complex span</th>
<th>Digit Span</th>
<th>AV-RT</th>
<th>CPS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Listening span (Recall %)</td>
<td>STM storage (List length)</td>
<td>Speed (ms)</td>
<td>Allocation (List length)</td>
</tr>
<tr>
<td><strong>M</strong></td>
<td>58.4</td>
<td>5.11</td>
<td>731.14</td>
<td>4.20</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>17.72</td>
<td>.91</td>
<td>136.94</td>
<td>.79</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>25-100</td>
<td>3 - 7</td>
<td>461-1056</td>
<td>2 - 6</td>
</tr>
<tr>
<td><strong>α</strong></td>
<td>.73</td>
<td>.77</td>
<td>.97</td>
<td>.70</td>
</tr>
</tbody>
</table>

**Note:** RT - Reaction time; STM - Short-term memory; AV-RT - Auditory-visual reaction time; CPS - Concurrent processing-storage task; α - Cronbach’s co-efficient of reliability
**Correlation and partial correlation matrix for all measures and age (N=65)**

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>Complex span (Recall %)</th>
<th>Digit Span STM storage (List length)</th>
<th>AV-RT Speed (ms)</th>
<th>CPS Allocation (List length)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1</td>
<td>.372**</td>
<td>.450**</td>
<td>-.445**</td>
<td>.372**</td>
</tr>
<tr>
<td>Complex span</td>
<td>-</td>
<td>1</td>
<td>.465**</td>
<td>-.414**</td>
<td>.421**</td>
</tr>
<tr>
<td>Digit span</td>
<td>-</td>
<td>.374**</td>
<td>1</td>
<td>-.249*</td>
<td>.564**</td>
</tr>
<tr>
<td>AV-RT</td>
<td>-</td>
<td>-.300*</td>
<td>-.068</td>
<td>1</td>
<td>-.275*</td>
</tr>
<tr>
<td>CPS</td>
<td>-</td>
<td>.356**</td>
<td>.490**</td>
<td>-.233</td>
<td>1</td>
</tr>
</tbody>
</table>

*Note: RT - Reaction time; STM - Short-term memory; AV-RT - Auditory-visual reaction time; CPS - Concurrent processing-storage task

* Correlation is significant at $\alpha = .05$ (2-tailed)

** Correlation is significant at $\alpha = .01$ (2-tailed)

Values below the diagonal represent partial correlations after controlling for age
Summary of hierarchical regression analysis for predicting complex span (N=65). Entry of predictors based on developmental memory literature (STM, Processing speed, Attentional allocation)

<table>
<thead>
<tr>
<th>Variable</th>
<th>β</th>
<th>ΔF</th>
<th>ΔR²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block 1 Age</td>
<td>.367**</td>
<td>9.21**</td>
<td>.135**</td>
</tr>
<tr>
<td>Block 2 Age, Digit span</td>
<td>.388**</td>
<td>9.43**</td>
<td>.121**</td>
</tr>
<tr>
<td>Block 3 Age, Digit span, AV-RT</td>
<td>-.286*</td>
<td>5.53*</td>
<td>.066*</td>
</tr>
<tr>
<td>Block 4 Age, Digit span, AV-RT, CPS</td>
<td>.166</td>
<td>1.46</td>
<td>.017</td>
</tr>
</tbody>
</table>

Note: * .05 (2 tailed), .01 (2 tailed)
Summary & Conclusions

Findings consistent with developmental memory literature:

- Each memory ability correlated with age (Bayliss et al., 2003; 2005)
- STM and Attentional Resource Allocation significantly correlated (after removing age)
- Speed did not correlate with STM or Allocation (after removing age). This could be because:
  - age related variance in STM and Allocation is unrelated to speed (e.g., Bayliss et al., 2005)
  - nature of the speeded task (task was too cognitively too simple)
  - independent developmental trajectories of the different abilities
Unique Contributions to Complex Memory

Span

- Age: 14% **
- STM Storage: 12% **
- Speed: 6% *
- Attentional Allocation: 1%
Finding that STM and Speed predicted Complex Memory Span is consistent with Bayliss et al. (2005)

Lack of significant contribution of Attentional Resource Allocation likely because this task was too similar to the STM task, i.e., it had a significant storage component.

E.g. Stimulus:- 2 cat 4 Response: cat 2
Future Directions

1) Use of multiple measures per construct to study contribution of working memory mechanisms to complex span

2) Examine the role of attentional mechanisms in complex span in greater depth using robust experimental measures (Unsworth & Engle, 2008; Portrat, Camos & Barrouillet, in press)
Acknowledgments

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Select References

