Specific Language and Working Memory Impairments: Evidence and Learning Patterns

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SRCLD 2011

Overview

- Working Memory: Components & measurement
- WM and Language: Are they separable?
- Distinct WM and Language Impairments
- Learning patterns of WMI and LI groups

Why working memory?

- Bates (1994)
  - Language involves a reconfiguration of mental & neural systems that ... serve at least some nonlinguistic functions
  - Fast enough to fall within memory constraints but clear and efficient enough for successful production and comprehension

Working Memory

- System/mechanisms
  - maintenance of task-relevant information
  - during the performance of a cognitive task
  - in the current focus of attention
- The ‘hub of cognition’
- An essential role in complex cognition
- More highly related to learning than any other factor

Domain-general constraints

- Haberlandt, 1997; Goldman-Rakic, 1992; Shah & Miyake, 2001; Kyllonen, 1996

Working Memory Components

- Baddeley & Hitch, 1974; Baddeley, 1986
- Other models: Cowan, 1999; Kane & Engle, 2000
Short-term Memory

- Brief retention of information
  - Domain-specific processors: phonological, visual, spatial features, and many others (e.g., semantic)
  - Recoding / dual coding
- Some common principles
  - Activation
  - Rehearsal
  - Interference
- Connects with existing knowledge
  Baddeley & Hitch, 1974; Gathercole, 1999; Kane & Engle, 2000

Central Executive

- Directs attention; controls & coordinates currently activated information
- Current focus of attention
  - Voluntary processing
  - Conscious of at the moment
  - Activated state; implicit WM?
- Domain-general resource drives relationship with other complex cognitive activities
  Baddeley, 1986; Cowan, 1999; Kane & Engle, 2000; Hassin et al., 2009

Mapping Measures to the Model

- Process sentence + recall
- Mental rotation = recall
- Chess configurations
- Corsi block

Questions

- Model and measure
  - Separate STM & executive components
  - Domain-specificity of STM
  - Domain-free processing resource
- Developmental sample (Alloway et al., 2004)

Idea

- To examine short-term and working memory processes in an independent sample of school-age children

Datasets

- Archibald & Joanisse (2009)
  - 9 schools
  - 400 screened
    - 94% English
    - Sentence recall (Redmond, 2003)
  - Nonword Rep (D&C, 1998)
  - 88 assessments
    - CELF-IV
    - AWMA
    - TONI
- Archibald et al. (in mulling)
  - 34 schools
  - 1387 screened
    - 85% English; 82% mother with some college education
- 2 samplings
  - AWMA study, n=178
  - Selected sample, n=392
Participants

- 16 urban; 4 rural schools
- 40 children randomly selected from large unselected database from each of 5 age groupings

<table>
<thead>
<tr>
<th>Age Group</th>
<th>J0-5-11</th>
<th>J0-6-11</th>
<th>J2-7-11</th>
<th>J0-8-11</th>
<th>J0-9-11</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>Female</td>
<td>17</td>
<td>21</td>
<td>17</td>
<td>20</td>
<td>20</td>
<td>96</td>
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<td>Male</td>
<td>9</td>
<td>14</td>
<td>23</td>
<td>16</td>
<td>20</td>
<td>82</td>
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<tr>
<td>Total</td>
<td>26</td>
<td>35</td>
<td>40</td>
<td>36</td>
<td>40</td>
<td>178</td>
</tr>
</tbody>
</table>

- Automated Working Memory Assessment (AWMA; Alloway, 2007)

AWMA

- Short-term memory
  - Phonological
    - Repeat numbers, words, nonwords
  - Visuospatial
    - Recall locations on a grid, blocks on a board, paths through a maze

- Working memory
  - Verbal
    - Backwards digit recall
    - Listening recall
      - Clocks eat **apples** true/false
      - Pianos play **music** true/false
      - Recall final words: apples, music
  - Visuospatial
    - Odd-one-out
    - Mr. X

Recall tallies: ‘4, 3, 5’
AWMA:

- Working memory
  - Visuospatial
    - Spatial Span

AWMA:

- Phonological STM
  - Digit recall
  - Word recall
  - Nonword recall
- Verbal WM
  - Listening recall
  - Counting recall
  - Backwards digit recall
- VSSP STM
  - Dot matrix
  - Block recall
  - Mazes memory
- VSSP WM
  - Odd one out
  - Mr. X
  - Spatial Span

AWMA: Results

<table>
<thead>
<tr>
<th></th>
<th>WM Proc</th>
<th>PhSTM</th>
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<tbody>
<tr>
<td>Digit recall</td>
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<td>.73</td>
<td>.37</td>
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<td>Odd one out</td>
<td>.79</td>
<td></td>
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<tr>
<td>Mr. X</td>
<td>.75</td>
<td></td>
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<tr>
<td>Spatial recall</td>
<td>.75</td>
<td></td>
</tr>
</tbody>
</table>

PCA; Eigenvalues > 1; Varimax rotation; factor loadings > 0.35

Summary: AWMA study

- Phonological STM
- Domain-free processing

- VSSP STM more difficult to distinguish (Gathercole & Pickering, 2000; Miyake et al., 2001)

WM and Language

- Are they separable?
- Different measures of the same underlying factors?
  - Phonological STM
  - Domain-general processing

WM & Language: Associations

- PhSTM
  - New word learning ➔ MANY STUDIES
  - Long, complex sentences ➔ SEVERAL STUDIES
- WM (complex span)
  - Reading & listening comprehension ➔ SEVERAL STUDIES

Gathercole, 2006; Adams & Gathercole, 2000; Daneman & Carpenter, 1980; King & Just, 1991
WM & Language: Separability

• Marked difficulty with aspects of grammar in SLI
• Intact syntactic processing in low WM groups d/t dementia (Caplan & Waters, 1999)
• Good/poor WM groups comparable simple sentence comprehension (Engle & Conway, 1998; Montgomery & Evans, 2009)

Idea

• Examine WM and language performance in a large group of school age children

Participants

• 34 schools; ~6000 invitations; SK to gr. 4
• 1387 participated
• Screening
  – Sentence recall (Redmond, 2003; Archibald & Joanisse, 2009)
  – Math fluency (Woodcock Johnson III)
  – Word/nonword reading (TOWRE)

Selected Sample

1. Typical screeners

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<th>5;0-5;11</th>
<th>6;0-6;11</th>
<th>7;0-7;11</th>
<th>8;0-8;11</th>
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<td>Low Screeners</td>
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<td>59</td>
<td>45</td>
<td>38</td>
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<td>44</td>
<td>78</td>
<td>113</td>
<td>86</td>
<td>71</td>
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Assessment Measures

- Select subtests from AWMA
- Composite Language Score (CELF-IV)
- Wechsler Abbreviated Scale of Intelligence (WASI) (WPPSI for under 6)

Other measures
- Sentence recall
- Grammaticality judgment (Miller et al., 2008)
- Rapid letter/picture naming
- (School learning measures)

Factor Analysis

<table>
<thead>
<tr>
<th>Language</th>
<th>PhSTM</th>
<th>VSSP</th>
<th>Verbal WM</th>
<th>VSSP WM</th>
<th>IQ</th>
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<tr>
<td>Concepts &amp; following directions</td>
<td>Digit recall</td>
<td>Dot matrix recall</td>
<td>Listening recall</td>
<td>Odd one out</td>
<td>Vocabulary</td>
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<tr>
<td>Recalling sentences</td>
<td>Nonword recall</td>
<td>Block recall</td>
<td>Counting recall</td>
<td>Spatial Span</td>
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<tr>
<td>Formulating sentences</td>
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Factor Correlations

<table>
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<th>2</th>
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<th>PIQ</th>
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<tr>
<td>WM Proc</td>
<td>Sentence Recall</td>
<td>Grammaticality Judgment</td>
<td>Rapid Letter Naming</td>
<td>Rapid Picture Naming</td>
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<tr>
<td>Language</td>
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<tr>
<td>PhSTM</td>
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<td>ns</td>
<td>.36**</td>
<td>.20**</td>
<td>.19**</td>
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<td>-.27**</td>
<td>-.22**</td>
<td>ns</td>
<td>ns</td>
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</table>

Partial correlations controlling for age; n = 372; **p < .001

Summary: WM & Language

- Separable factors
  - WM: Domain-free processing
  - PhSTM
  - Language
  - PIQ

- Separable impairments?

Specific Language Impairment: Theories

Domain-general
- Processing capacity
- Processing speed

Domain-specific
- Phonological processing
- Grammatical learning deficit

WM & Language: Distinct Impairments?

- Archibald & Joanisse, 2009
- \( n = 88 \)

Selected Sample Data

- Selected sample: 392 assessments
  - Language: CELF-IV
  - Working Memory: AWMA
  - (Nonverbal intelligence: WASI)

Cluster Analysis

- Subdivision of cases into homogeneous groups
- \( t \)-statistic plot
  - Comparing mean of the variable in cluster to overall mean

Cluster Analysis Results

Cluster Descriptives 1

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<tr>
<th></th>
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<th>Sex</th>
<th>Age (yrs)</th>
<th>Maternal Ed</th>
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<tr>
<td>Mixed</td>
<td>15</td>
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<td>7.3 ± 1.5</td>
<td>High school; some college*</td>
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<tr>
<td>SWMI</td>
<td>26</td>
<td></td>
<td>7.1 ± 1.0</td>
<td>Completed college</td>
</tr>
<tr>
<td>SLI</td>
<td>19</td>
<td>♂</td>
<td>8.1 ± 1.1*</td>
<td>Completed college</td>
</tr>
<tr>
<td>TD+</td>
<td>21</td>
<td>♂</td>
<td>7.4 ± 1.2</td>
<td>Completed college</td>
</tr>
<tr>
<td>Language+</td>
<td>19</td>
<td>♂</td>
<td>7.4 ± 1.3</td>
<td>Completed college</td>
</tr>
</tbody>
</table>
Summary: Specific Impairments

• Deficits in language and WM often co-occur
  — However, subgroups with specific impairments do exist

• Does WM impact language learning?
  — The case of SWMI

Leonard et al., 2007; Waters & Caplan, 2005

WM Impacts on Language Learning

• Causal

• Limiting

• Developmental

WM Constraints on Language

• PhSTM
  — retains activated features
  — new learning; rechecking

• WM
  — Attention-demanding situations
    • Maintain active representations
    • Suppress/abandon irrelevant activations
    • Long distance dependencies

Engle & Conway, 1998

WM&L: Developmental Relationship

• Demands on new learning diminishes as long-term language knowledge increases
  — Lexical/grammatical (bidirectional) bootstrapping
    (Marchman & Bates, 1994)

• Domain-relevant mechanisms may become more domain-specific over time
  (Karmiloff-Smith, 1998)
  — Emerging modularity

Idea

• Examine profile designations across development from our previous samples
**2 studies**

**Study 1**  
(Archibald & Joanisse, 2009)  
- $n = 88$

**Study 2**  
(Archibald et al.)  
- Selected Sample  
- $n = 392$

- CELF-IV
- AWMA

- SLI, SWMI, Mixed, Typical

**Developmental Trends**

<table>
<thead>
<tr>
<th></th>
<th>Typical</th>
<th>SLI</th>
<th>SWMI</th>
<th>Mixed</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 yr olds</td>
<td>67%</td>
<td>10%</td>
<td>13%</td>
<td>10%</td>
</tr>
<tr>
<td>6 yr olds</td>
<td>68%</td>
<td>0%</td>
<td>18%</td>
<td>15%</td>
</tr>
<tr>
<td>7 yr olds</td>
<td>70%</td>
<td>7%</td>
<td>16%</td>
<td>7%</td>
</tr>
<tr>
<td>8 yr olds</td>
<td>64%</td>
<td>19%</td>
<td>6%</td>
<td>10%</td>
</tr>
<tr>
<td>9 yr olds</td>
<td>72%</td>
<td>26%</td>
<td>0%</td>
<td>2%</td>
</tr>
</tbody>
</table>

**Study 1**  
Typical: 38%  
SLI: 8%  
SWMI: 26%  
Mixed: 25%

**WM&L: Development**

- Cross-sectional data  
  - SWMI decreases  
  - Mixed profile decreases  
  - SLI increases  
- Impact of WMI and LI

**Languages**
- Grammaticality judgment
- Story retelling (SRCLD, 2009)

**Related Processes**
- Rapid automatic naming
- School learning
- Divided attention (SRCLD, 2011 – Levese)
- Motor speech & NwrdRep – impact on LI not WMI (with Munson; SRCLD, 2010; In preparation)
- Classroom observation – similar social, behavioural, academic characteristics (SRCLD, 2009; CLTT – in press)
- Intervention – domain-specific effects (SRCLD, 2010; CLTT – in press)

**Working Memory**
- Hebb learning (In preparation)
- Paired associate learning
- Cognitive load (SRCLD, 2011 – Harder)

**WM in Word Learning**

- Beyond PhSTM capacity
- Formation of long-term phonological representations
- One aspect: sequence learning  
  - Hebb implicit learning effect

**Hebb Learning**

- 2756139
- 7632591
- 9563217
- 7632591
- 6327915
- 7632591

Donald Hebb, 1961
Hebb Repetition Effect

• Domain general
  – Verbal
  – Visually presented verbal information
    • Cross-modality learning via recoding
  – Spatial

• Domain-general mechanism involved in long-term learning of serial order information

Page et al., 2006; Mosse & Jarrold, 2008; Bayliss et al., 2005; Couture & Tremblay, 2006

Idea

• To examine long-term sequence learning in children with SLI, SWMI, Mixed, or typical development with PhSTM demands equated

Participants

• SLI, n=15
• SWMI, n=8
• L&WMI, n=8
• Typical, n=25
• Age: 8.5 years ± 1
• Males: 29/56
• A&J, 2009

Cross-modality Hebb Learning

A&J, 2009

Recall list by pointing in an array in the order seen.

Hebb Learning: Factors

• List type: Hebb > filler
• Half: first / second half
• Modality: visual / verbal

• Predicted interactions:
  – List x half: Hebb > filler on 2nd half
  – List x modality: Hebb verbal > Hebb visual

A&J, 2009

Hebb Learning: TD Results

A&J, 2009

• TD group only

Mosse & Jarrold, 2008
**Hebb Learning: TD Results**

- TD group only
- *Hebb implicit learning*
- *Sequence learning across modalities*

**Hebb Learning: Group Results**

- Implicit cross-modal sequence learning in TD 8-9 yr olds
- Children with WM Impairment showed reduced implicit learning
- Children with Language Impairment showed reduced learning from auditory modality

**Studies**

**Language**
- Grammaticality judgment
- Story retelling (SRCLD, 2009)

**Related Processes**
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**WM, Language, & School Learning**

- WM better predictor of school success than IQ
- Language impairments associated with learning difficulties across the curriculum

Mosse & Jarrold, 2008

A&J, 2009

Johnson, 2001; Evans et al., 2009; Joanisse et al., 2000; Chiat, 2001

SRCLD, 2009 – CLIT – in press

A&J, 2009

SRCLD, 2010; In preparation

SRCLD, 2010; In preparation
Idea

- To explore how language, WM, PhSTM, and PIQ account for children's school learning

Participants & Measures

**Participants**
- Selected sample
  - 6-9 yrs; n = 344

**Predictors**
- CLS
- WM
- PhSTM
- PIQ

**Dependent variables**
- Math fluency
- Calculations
- Sight word reading
- Nonword reading
- Reading fluency
- Phonological awareness

Results: Significant Predictors

<table>
<thead>
<tr>
<th>Std Tests</th>
<th>Predictors</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math Fluency</td>
<td>Language (7.5%), PIQ (4%)</td>
<td>19%</td>
</tr>
<tr>
<td>Calculations</td>
<td>Language (10%), PIQ (2.2%), WM (1.4%)</td>
<td>30%</td>
</tr>
<tr>
<td>Word Reading</td>
<td>Language (11.5%), WM (1.7%), PhSTM (1.4%)</td>
<td>24%</td>
</tr>
<tr>
<td>Nonword Reading</td>
<td>Language (5%), WM (1%), PIQ (1.5%) PhSTM (1.2%)</td>
<td>24%</td>
</tr>
<tr>
<td>Reading Fluency</td>
<td>Language (16.5%), PIQ (1.3%), WM (1.1%)</td>
<td>38%</td>
</tr>
<tr>
<td>Phonological Awareness</td>
<td>Language (3.4%), PhSTM (1.8%), PIQ (1.4%)</td>
<td>15%</td>
</tr>
</tbody>
</table>

Significant Predictors: Thoughts

- Language is a better predictor of school learning than WM or IQ
  - Also taps WM
  - Measuring crystallized knowledge / LTM
- Population of interest
- Measurement

Conclusions

- WM measures tap phonological short-term memory; domain-general controlled attention
- WM components separable from language abilities, nonverbal intelligence
- WM & language impairments are separable also

Conclusions

- WM and/or language impairment have different impacts on learning
  - Language: auditory learning; school learning
  - WM: learning efficiency, reading
- Language is a better predictor of school learning than WM or IQ
Directions

- Developmental patterns related to WM, language, and learning
- Impact of WMI on language, broadly defined
- Intervention

Thank you!

M. Sheperd; A. Desroches; J. Aucoin; S. Devraj; L. Spiegel; J. Cott; M. Taylor; F. Pardhan; A. White; A. Beier; L. Cryderman; B. Jeronimo; B. Rose; A. Martin; N. Pounds; M. Pinnloss; C. Cermak; K. Brittain; J. Berger; R. Aupperle; A. Partridge; S. Clother; L. Goldberg; L. Urbanak; A. Canton; E. Sterling; B. Adamson; E. Broxterman; J. Merritt; E. Robb; A. Roth; S. Wener; J. Paradis; C. Brown; A. Bender; K. Harder; L. Pauls; T. Urn; R. Merkley; J. Aikman; S. Beukema; T. Levee; J. Butt; J. Tsi; T. Ramnarain; J. Heracli; L. Vannus; A. McDermid; E. Lipari; A. Dodge; R. Nadler; J. Brubacher; S. Rivers; H. Molyneaux; A. Remari; S. Davis; S. Nancekivel; E. Lavolette; C. Schlesinger; M. Ditmars; M. Brown; A. Dirks; E. Gillesen; S. Hellen; M. Fraser; A. Ingram; J. Nyentap; C. Arsenaud; J. Davaller; S. Hansen; J. Weber; S. Rainham; K. Foo; J. Preston; R. Flok; D. Alasaka; L. Frier; A. Baker; K. Terpstra; H. Brown; K. Doyle; K. Bryant; L. Vanderlaan; A. Ballah; J. Utflugt; D. D’Alessandro; M. Holmes; J. Wilson; L. Greenwood; S. Sampiero; M. Lopez; A. McDonald; N. Nosworthy; C. Stanescu; M. Hurst; S. Huang; Members of the Language & Memory Group 2007-8; 2009-10; Staff at Port Burwell School 2008; Many principals, teachers, secretaries!

Collaborators:
- Marc Joanisse
- Daniel Ansari
- Janis Oram Cardy

Funding:
- Natural Sciences and Engineering Research Council 371201-2009

Supplemental

- AWMA – 3 components
- Discriminant function for clusters
- Paired associate learning
- Language subtest predictors for school learning
- Cluster differences in school learning
- Predictors of grammaticality judgment & RAN

Results

<table>
<thead>
<tr>
<th></th>
<th>Component 1</th>
<th>Component 2</th>
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<td>.32</td>
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</tr>
</tbody>
</table>

PCA; Eigenvalues > 1; Varimax rotation; Factor loadings > 0.4

AWMA study

<table>
<thead>
<tr>
<th></th>
<th>Component 1</th>
<th>Component 2</th>
<th>_component 3</th>
<th>Component 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digit recall</td>
<td>.80</td>
<td></td>
<td>.84</td>
<td></td>
</tr>
<tr>
<td>Word recall</td>
<td>.84</td>
<td></td>
<td>.75</td>
<td></td>
</tr>
<tr>
<td>Nonword recall</td>
<td>.82</td>
<td></td>
<td>.78</td>
<td></td>
</tr>
<tr>
<td>Dot matrix</td>
<td>.78</td>
<td></td>
<td>.78</td>
<td></td>
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<tr>
<td>Block recall</td>
<td>.40</td>
<td></td>
<td>.36</td>
<td></td>
</tr>
<tr>
<td>Mazes memory</td>
<td>.44</td>
<td></td>
<td>.51</td>
<td></td>
</tr>
<tr>
<td>Listening recall</td>
<td>.37</td>
<td></td>
<td>.79</td>
<td></td>
</tr>
<tr>
<td>Backward digit recall</td>
<td>.67</td>
<td>.32</td>
<td>.36</td>
<td></td>
</tr>
<tr>
<td>Counting recall</td>
<td>.73</td>
<td></td>
<td>.33</td>
<td></td>
</tr>
<tr>
<td>Odd one out</td>
<td>.54</td>
<td></td>
<td>.64</td>
<td></td>
</tr>
<tr>
<td>Spatial recall</td>
<td>.63</td>
<td></td>
<td>.46</td>
<td></td>
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</tbody>
</table>

PCA; Eigenvalues > 0.7; Varimax rotation
AWMA: PCA Scree Plot

Discriminant Function

<table>
<thead>
<tr>
<th>Added with CLS:</th>
<th>Classification of Clusters</th>
</tr>
</thead>
<tbody>
<tr>
<td>WM</td>
<td>96%</td>
</tr>
<tr>
<td>Odd one out</td>
<td>80%</td>
</tr>
<tr>
<td>Counting recall</td>
<td>75%</td>
</tr>
<tr>
<td>Spatial recall</td>
<td>72%</td>
</tr>
<tr>
<td>Block Design</td>
<td>58%</td>
</tr>
<tr>
<td>Matrix reasoning</td>
<td>61%</td>
</tr>
<tr>
<td>PIQ</td>
<td>60%</td>
</tr>
</tbody>
</table>

Selected Sample

Discriminant Function

<table>
<thead>
<tr>
<th>Added with WM:</th>
<th>Classification of Clusters</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLS</td>
<td>96%</td>
</tr>
<tr>
<td>Concepts &amp; FD</td>
<td>81%</td>
</tr>
<tr>
<td>Recalling sentences</td>
<td>77%</td>
</tr>
<tr>
<td>Formulating sentences</td>
<td>77%</td>
</tr>
<tr>
<td>Formulating + Odd One Out</td>
<td>67%</td>
</tr>
<tr>
<td>All other 2-test combos</td>
<td>58-64%</td>
</tr>
</tbody>
</table>

Selected Sample

Paired associate learning

- 2 conditions: words; nonwords
- 10 trials each (max score 40)

Paired associate: Results

Learning Relationships: Results

<table>
<thead>
<tr>
<th></th>
<th>Words</th>
<th>Nonwords</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hebb 2\text{nd} half – visual</td>
<td>.17</td>
<td>.38*</td>
</tr>
<tr>
<td>PhSTM</td>
<td>.24</td>
<td>.44*</td>
</tr>
<tr>
<td>WM</td>
<td>.34*</td>
<td>.44*</td>
</tr>
<tr>
<td>CLS</td>
<td>.20</td>
<td>.48*</td>
</tr>
<tr>
<td>PIQ</td>
<td>.21</td>
<td>.43*</td>
</tr>
</tbody>
</table>

*\( p < .01 \)
Word Learning: Summary

- Nonword/new learning taps multiple cognitive processes
- Particularly challenging for children with LI – Auditory modality
- Children with WMI less efficient learning across modalities, word type

Language Subtest Predictors: School Learning

<table>
<thead>
<tr>
<th>Std Tests</th>
<th>Predictors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math Fluency</td>
<td>Formulating Sentences &amp; Concepts + FD</td>
</tr>
<tr>
<td>Calculations</td>
<td></td>
</tr>
<tr>
<td>Reading Fluency (+PhSTM)</td>
<td></td>
</tr>
<tr>
<td>Word Reading (+PIQ)</td>
<td></td>
</tr>
<tr>
<td>Nonword Reading</td>
<td>Phonological Awareness</td>
</tr>
</tbody>
</table>

Cluster Differences: Summary

- Co-occurring L&WMI ➔ lowest attainment scores
- SLI & SWMI ➔ lower reading & math fluency scores than TD but not distinguished
References


