Examining the Utility of Cognitive Measures for Predicting Mathematics Achievement and Differential Response to a Kindergarten Mathematics Intervention

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Background & Context

• Early mathematics intervention screening
  – Students at risk for mathematics difficulties vs. average achieving peers on cognitive (Bull et al., 1999; Geary, 2004; Geary et al., 2007).
  – Cognitive factors associated with mathematics difficulties (Fuchs et al., 2005; Geary et al., 1999; Gersten et al., 2005; Krajewski & Schneider, 2009; Swanson & Jerman, 2006).

• Predicting response to mathematics instruction
  – Students with underdeveloped cognitive skills struggle with foundational number sense concepts (Mazzocco & Kover, 2007; Mazzocco & Thompson, 2005).
  – Optimal interventions could be determined based on cognitive profiles (Yoder & Compton, 2004).
Research Questions

1. How did cognitive assessments administered in the fall predict fall mathematics performance, above and beyond fall CBM mathematics measures?

2. Did cognitive measures explain student response to the intervention? That is, was there evidence of differential response to a small-group kindergarten whole number intervention based on cognitive assessment results?
Setting

• Participating students were recruited from 29 full day kindergarten classrooms from 17 schools in three medium-sized school districts in the Pacific Northwest.

• Districts consisted of majority white populations (76.5–92.5%), fairly equal gender distributions (48.1–51.4% percent male), 9.9–19.8% Hispanic or Latino populations, and median household incomes ranging from approx. $45,000–$60,000 (U.S. Census Bureau, 2009).
Participants

Note: All students in the 29 participating classrooms received core math instruction from the Early Learning in Mathematics curriculum (Chard et al., 2008).

ROOTS Study

• Half of the participating classrooms were treatment classrooms where the ROOTS intervention was offered to a handful of at-risk students.
• 140 students were selected to participate in the ROOTS intervention or serve as matched controls in control classrooms.

Cognitive Study

• Majority of sample scored below the 42\textsuperscript{nd} percentile on the TEMA pretest
• The final consented sample consisted of 58 students who received the Roots intervention and 404 students who did not.
Sample Demographics

Table 2
District and Cognitive Sample Demographics Gathered from District Report

<table>
<thead>
<tr>
<th>District</th>
<th>Special Education</th>
<th>English Learner</th>
<th>Free-Reduced Lunch</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>13.8</td>
<td>13.7</td>
<td>44.9</td>
</tr>
<tr>
<td>B</td>
<td>11.7</td>
<td>11.2</td>
<td>34.0</td>
</tr>
<tr>
<td>C</td>
<td>12.2</td>
<td>8.3</td>
<td>50.4</td>
</tr>
<tr>
<td>Cognitive Sample</td>
<td>10.0</td>
<td>49.0</td>
<td>72.3</td>
</tr>
</tbody>
</table>

*Note. All values are percentages.*
Intervention: ROOTS

- Small group instruction (3-5 students)
  - led by instructional assistant
  - separate room or back of classroom
  - supplemental to core instruction
- 3 times per week (50 lessons total)
- 20 minutes long
  - 4-5 math activities per lesson (counting and cardinality, number operations, and base 10/place value)
  - Explicit approach and scripting supports both students and instructor.
- Administered January–May
Research Design

• Quasi-experimental design
  – random assignment of classrooms to condition
    • Blocking on teachers’ experience with ELM (Early Learning in Mathematics) curriculum & school.
  – teacher selection of ROOTS students

• Intervention effect analyses were conducted within the existing framework of the intervention study with students nested within classrooms and classrooms nested within condition.
Measures

• Academic
  – Early Numeracy CBM
    • Oral Counting
    • Number Identification
    • Quantity Discrimination
    • Missing Number
  – Test of Early Mathematics Ability – 3rd Edition (TEMA-3)

• Cognitive
  – Weschler Abbreviated Scale of Intelligence (WASI)
    • Vocabulary
    • Matrix Reasoning
  – Digit Span Forward and Backward
Data Collection

• All measures were individually administered.
• Utilized trained data collection staff with extensive experience in collecting educational data.
• Inter-rater reliability coefficients of at least .90 prior to collecting data with students.
• Follow-up trainings were conducted prior to each data collection period.
Results

• WASI cognitive measures explained a statistically significant, but relatively small amount of variance in TEMA scores above and beyond EN-CBM scores, $\Delta R^2 = .03, p < .05$.

• Digit span forward was a statistically significant predictor of mathematics performance in the at-risk sample.

• Cognitive variables explained more variance in the mathematics performance of the at-risk population compared to the entire sample, $\Delta R^2 = .05, p < .05$. 
Results (cont.)

• Statistically significant gains among students provided with ROOTS over those in control classrooms on TEMA standard scores, $t = 2.19$, $df = 27$, $p = .0371$ (Clarke et al., 2013).

• Cognitive performance was not associated with differential response to the ROOTS intervention.
### Correlations & Descriptive Statistics

#### Table 3

**Mathematics Achievement and Cognitive Measures Administered: Correlations and Descriptive Statistics (N = 462)**

<table>
<thead>
<tr>
<th>Measures</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. WASI vocabulary</td>
<td>–</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>13.35</td>
<td>9.01</td>
</tr>
<tr>
<td>2. WASI matrix reasoning</td>
<td>.21</td>
<td>–</td>
<td></td>
<td></td>
<td></td>
<td>6.02</td>
<td>3.73</td>
</tr>
<tr>
<td>3. Digit span forward</td>
<td>.43</td>
<td>.11²</td>
<td>–</td>
<td></td>
<td></td>
<td>4.90</td>
<td>1.84</td>
</tr>
<tr>
<td>4. Digit span backward</td>
<td>.46</td>
<td>.33</td>
<td>.40</td>
<td>–</td>
<td></td>
<td>1.45</td>
<td>1.39</td>
</tr>
<tr>
<td>5. EN-CBM total</td>
<td>.41</td>
<td>.23</td>
<td>.32</td>
<td>.38</td>
<td>–</td>
<td>38.34</td>
<td>27.86</td>
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<tr>
<td>Number ID</td>
<td>.37</td>
<td>.21</td>
<td>.22</td>
<td>.31</td>
<td>.91</td>
<td>17.49</td>
<td>15.49</td>
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<td>Oral counting</td>
<td>.38</td>
<td>.18</td>
<td>.38</td>
<td>.35</td>
<td>.71</td>
<td>13.76</td>
<td>9.09</td>
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<tr>
<td>Quantity discrimination</td>
<td>.27</td>
<td>.13¹</td>
<td>.26</td>
<td>.28</td>
<td>.81</td>
<td>5.11</td>
<td>6.33</td>
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<tr>
<td>Missing number</td>
<td>.15</td>
<td>.23</td>
<td>.15¹</td>
<td>.27</td>
<td>.63</td>
<td>1.98</td>
<td>3.26</td>
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<tr>
<td>TEMA pre-test</td>
<td>.45</td>
<td>.27</td>
<td>.34</td>
<td>.39</td>
<td>.76</td>
<td>12.51</td>
<td>6.19</td>
</tr>
<tr>
<td>TEMA post-test</td>
<td>.34</td>
<td>.31</td>
<td>.32</td>
<td>.49</td>
<td>.57</td>
<td>27.84</td>
<td>7.81</td>
</tr>
</tbody>
</table>

*Note. All values significant at p < .001 unless otherwise noted. ¹ p < .01 ² p < .05*
Hierarchical Regression: Entire Sample

Table 4
Hierarchical Regression Analysis Predicting TEMA Scores with CBM Pretest Scores & Cognitive Variables for Total Sample (N = 462)

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Model 1</th>
<th></th>
<th></th>
<th>Model 2</th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>SE B</td>
<td>β</td>
<td>B</td>
<td>SE B</td>
<td>β</td>
</tr>
<tr>
<td>Intercept</td>
<td>65.41***</td>
<td>0.66</td>
<td></td>
<td>59.97***</td>
<td>1.69</td>
<td></td>
</tr>
<tr>
<td>Oral counting</td>
<td>0.38***</td>
<td>0.04</td>
<td>0.30</td>
<td>0.29***</td>
<td>0.05</td>
<td>0.23</td>
</tr>
<tr>
<td>Number ID</td>
<td>0.33***</td>
<td>0.03</td>
<td>0.45</td>
<td>0.29***</td>
<td>0.03</td>
<td>0.40</td>
</tr>
<tr>
<td>Quant. discrim.</td>
<td>0.19*</td>
<td>0.08</td>
<td>0.11</td>
<td>0.20**</td>
<td>0.08</td>
<td>0.11</td>
</tr>
<tr>
<td>Missing number</td>
<td>0.27*</td>
<td>0.13</td>
<td>0.08</td>
<td>0.25</td>
<td>0.13</td>
<td>0.07</td>
</tr>
<tr>
<td>WASI vocab.</td>
<td>0.31**</td>
<td>0.10</td>
<td>0.11</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>WASI matrix</td>
<td>0.36</td>
<td>0.17</td>
<td>0.07</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digit forward</td>
<td>0.32</td>
<td>0.22</td>
<td>0.05</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Digit back</td>
<td>0.35</td>
<td>0.30</td>
<td>0.04</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Note. (ΔR² = .03, p < .05) * p ≤ .05. ** p < .01. *** p < .001.
Hierarchical Regression: At-risk Sample

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Model 1</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>SE B</td>
<td>β</td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td></td>
<td>62.26***</td>
<td>1.19</td>
<td></td>
<td>53.93***</td>
</tr>
<tr>
<td>Oral counting</td>
<td></td>
<td>0.39**</td>
<td>0.13</td>
<td>0.29</td>
<td>0.31*</td>
</tr>
<tr>
<td>Number ID</td>
<td></td>
<td>0.36***</td>
<td>0.09</td>
<td>0.39</td>
<td>0.33***</td>
</tr>
<tr>
<td>Quant. discrim.</td>
<td></td>
<td>-0.26</td>
<td>0.35</td>
<td>-0.10</td>
<td>-0.13</td>
</tr>
<tr>
<td>Missing number</td>
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<td>1.07</td>
<td>0.65</td>
<td>0.21</td>
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<tr>
<td>WASI vocab.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.08</td>
</tr>
<tr>
<td>WASI matrix</td>
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<td></td>
<td></td>
<td></td>
<td>0.63</td>
</tr>
<tr>
<td>Digit forward</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.88*</td>
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<tr>
<td>Digit back</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.54</td>
</tr>
</tbody>
</table>

Note. (ΔR² = .05, p < .05) * p ≤ .05. ** p < .01. *** p < .001.
Conclusions

• Cognitive measures were able to explain a small, but unique portion of the variance in kindergarten students’ mathematics performance above and beyond achievement measures.

• No evidence of differential response to ROOTS intervention based on cognitive skills.
  – Question of power due to the relatively small sample size.
Future Research

• Investigate the ability of specific cognitive measures to predict math performance above and beyond academic screeners esp. for at-risk learners.

• Evaluate the interaction between cognitive skills and early mathematics interventions with sufficient sample sizes to develop interventions that adjust for cognitive profiles to improve mathematics performance.
References


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