Exploring the Value of Working Memory Training When Combined with Skills-Based Instruction in Reading Comprehension for Young At-Risk Students

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Background and Purpose

For students at risk for learning difficulties, a belief in the efficacy of skills-based instruction seems well founded. When implemented with fidelity, carefully scripted programs in reading, writing, and math have benefited numerous at-risk students (e.g., L. Fuchs, Fuchs, & Compton, 2012; Graham & Perin, 2007; Kroesbergen & VanLuit, 2003). As importantly, however, a skills-based approach fails to advance the progress of all students. Multiple research teams grappling with school-based implementations of response-to-intervention (RTI) have independently demonstrated the veracity of this claim (e.g., D. Fuchs, Fuchs, & Compton, 2004; Vaughn et al., 2010).

Cognitively focused instruction is a well-known, if controversial, alternative for students at risk for learning difficulties (cf. Learning Disabilities Association, 2010). Arguably, the most popular variant targets putative cognitive processes responsible for academic problems. Working memory (WM) is a cognitive skill that has received much attention in this regard (e.g., Shipstead, Redick, & Engle, 2012). WM refers to the capacity to store information temporarily when engaging in cognitively demanding activities (Baddeley, 1986). Compared to short-term memory, WM plays a more influential role in children’s academic performance (Baddeley, 1986). This is because many academic tasks involve multiple steps with intermediate solutions that must be remembered for a short time to accomplish the task at hand (Shah & Miyake, 1996). For example, during reading comprehension, children must maintain previously learned information while simultaneously integrating incoming information as they progress through a text (Cain, Oakhill, & Bryant, 2004).

Very few studies on at-risk students with poor WM difficulties showed that they could be trained to be more proficient on WM tasks, with this training apparently leading to stronger academic achievement (e.g., Holmes, Gathercole, & Dunning, 2009). Most prior studies on WM training, however, have focused on WM training in the absence of academic instruction. The purpose of the present study was to combine WM training with skills-based reading comprehension instruction for first-grade at-risk students. We collected data from two first-grade cohorts in two consecutive years. Children in each cohort was assigned randomly to the same three study groups. One group received WM training and instruction in decoding/fluency (DF) and reading comprehension (Comp); one group received DF and Comp without WM training; and the remaining students were controls. We examined three questions: 1) whether students in the WM+DF+Comp group would improve on WM and reading skills compared to the control group. 2) Whether the DF+Comp group would improve their reading skills relative to controls. 3) Whether the WM+DF+Comp group would show greater improvement on reading skills compared to the DF+Comp students.

Participants

Participants were from an urban public school system in a medium-size city in the Southeast. The recruitment and random assignment of students were the same for both cohorts. Specifically, teachers were asked to nominate poorest readers without behavior or attendance problems. For English language
learners, they were required to have Early Advanced Proficiency in English. We obtained parental consent for 90% of students who were then screened in 2 steps. They were tested on sight word and decoding efficiency subtests of TOWRE; on rapid letter naming and sound naming tasks; on Word Identification Fluency (A); and word identification and word attack subtests of WRMT. One reading factor score was calculated for each student. The top 20% of the students were eliminated. The remaining students were administered WASI Vocabulary and Matrix Reasoning subtests. Those with T scores equal to or greater than 37 on one or the other subtest were included. With the two cohorts combined, we had 192 students from 13 elementary schools. There were 65 students in the WM+DF+Comp group, 60 in the DF+Comp group, and 67 controls.

Student demographic data are presented in Table 1. Across the two cohorts, the study groups were comparable on students’ sex, $\chi^2(2) = .57, p = .75$, race, $\chi^2(6) = 2.81, p = .83$, school-identified disability, $\chi^2(2) = .43, p = .81$, English Language Learner (ELL) status, $\chi^2(2) = .99, p = .61$, and Free/Reduced Lunch Status, $\chi^2(2) = .29, p = .86$. There were no pre-treatment differences among the groups across cohorts, $F(2, 189) = .16 - 2.28, ps = .11 - .85$, on any of outcome measures.

**Intervention**

Tutoring took place outside the classroom (e.g., library, reading clinic, hallway) during the regular school day. Tutors were masters and doctoral students, post-doctoral fellows, and full-time employees of the project. Each student was tutored three times a week for 20 weeks, for a total of 60 sessions. Each DF session lasted 25 minutes in cohort 1 and 20 minutes in cohort 2. Each Comprehension session lasted 20 minutes in cohort 1 and 15 minutes in cohort 2. For both cohorts, DF activities addressed letter sounds, sight words, and decodable words, and required the reading of connected text with fluency and accuracy. Comprehension activities focused on the development of vocabulary and background knowledge, identifying ambiguous pronouns, and constructing retells, main ideas, and inferences. All tutoring activities were scripted and included correction procedures for incorrect student responses. We attempted to maintain student attention and engagement by embedding “games” to practice the reading-related skills and by implementing a point system.

In cohort 1, WM activities were embedded in DF and Comprehension activities. WM was addressed by complex span tasks, dual-task performance, and updating tasks. In cohort 2, there was one 5-minute WM version of phonological processing training and one 5-minute WM version of comprehension training in each session. WM activity for Cohort 2 involved complex span tasks and dual-task performance. For WM training in both cohorts, tutors were required to keep track of the student’s high score and the number of trials attempted for each activity. Tutors also followed the “adaptive rule” to ensure that the difficulty of the activities was appropriately challenging. That is, as students improved their performance, they were challenged to test their working memory by attempting trials equal to their highest score from the previous session. If students failed a trial, then they attempted another trial at that same level instead of immediately moving down a level.

There were 4 live observations of tutoring implementation during intervention in both cohorts. The overall fidelity percentages for the 4 observed DF sessions were 97%, 95%, 97%, and 93%. The overall fidelity percentages for the 4 observed Comp sessions were 98%, 94%, 96%, and 93%. The overall fidelity percentages for WM training were 96%, 95%, 97%, and 96%.

**Data Collection**

Data were collected by trained research assistants (RAS) at pre- and post-treatment. Before pretesting, they received extensive test training. Project staff explained test administration guidelines; modeled the proper administration of each test; and required the RAs to role play test administration with other RAs. They practiced each of the 5 batteries of tests with their testing partners for 4 hours. Posttest training was
Data Analysis and Results

We created factor scores to index working memory, short-term memory, word reading, non-word reading, reading comprehension performance, listening comprehension score, and phonological awareness, which, compared to raw scores, reduce the task-specific variances and reflect common variences across tasks (Darlington, 2004). Specifically, we computed pre-treatment and post-treatment factor scores for (1) Working Memory, based on (a) Working Memory Test Battery (WMTB)-Listening recall and (b) WMTB- Counting Recall; (2) Short-term Memory, based on (a) WMTB-Digit Recall and (b) WMTB- Non-word List Recall; (3) Word reading, based on (a) Test of Word Reading Efficiency (TOWRE)-Sight Word Efficiency, (b) Word Identification Fluency, and (c) Woodcock Reading Mastery Test (WRMT)-Word Identification; (4) Non-word reading, based on (a) TOWRE-Phonemic Decoding Efficiency, and (b) WRMT -Word Attack, (5) Phonological Awareness, based on (a) Sound Segmenting, (b)Timed Sound Blending, and (c) Untimed Sound Blending, (6) Reading Comprehension, based on (a) Iowa Test of Basic Skills (ITBS), and (b) WRMT – Passage Comprehension, and (7) Listening Comprehension, based on (a) WRMT – Listening Comprehension, (b) Qualitative Reading Inventory (QRI) - Retell, and (c) QRI - Question. We also examined updating as one outcome; however, because we only had one measure of pre- and post-updating, we could not create factor scores, and we used the raw score for updating instead.

We investigated group effects on post-treatment working memory, short-term memory, updating, word reading, non-word reading, reading comprehension, and listening comprehension. Because the students in our study were from different schools, we first calculated the intra-class correlation (ICCs) using SPSS to examine potential school effects. The results showed there were small to medium school effects (ICC = 3%~19%) on the outcome measures. Thus, in all of our analyses, we employed two-level models in which student (Level 1, n = 192) were nested within schools (Level 2, n = 15). In the student level, we examined the treatment effects by controlling relevant pre-treatment score (e.g., we controlled for the pre-treatment word reading factor score when evaluating post-treatment word reading factor score). Because we did not find cohort effects or interaction between cohort and study groups on post-treatment outcomes (ps > .10), we did not control for cohort in our analyses. After controlling for the pre-treatment factor score, compared to the Control, the DF+Comp treatment had moderate effects on word reading, reading comprehension, and phonological awareness (effect sizes Hedges g = .40-.63, ps < .05), but did not have a significant effect on other measures. In contrast, the WM+DF+Comp treatment had moderate effects on word reading, working memory, and phonological awareness (effect sizes Hedges g = .33-.43, ps < .05), but did not have significant effects on any other measures. The comparison between the two treatment groups shows that WM+DF+Comp treatment significantly outperformed the DF+Comp treatment on working memory (effect sizes Hedges g = .33, p < .05).

Conclusions

In summary, the DF+Comp and the WM+DF+Comp groups showed more improvement on word reading and phonological awareness skills than students in the control group. This result was expected, because both treatment groups targeted word and phonological awareness skills. Also, the DF+Comp group showed more improvement than controls on reading comprehension, which was also expected because the DF+Comp treatment targeted comprehension skills training. However, the WM+DF+Comp group did not show greater improvement relative to controls on reading comprehension. Taken together, our findings suggest that, for young at-risk students, WM training improves WM but does transfer to reading skills.
Table 1
Student Demographics by Tutoring Condition and Tutoring Cohort

<table>
<thead>
<tr>
<th></th>
<th>DF+Comprehension</th>
<th>WM+DF+Comprehension</th>
<th>Control</th>
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<tbody>
<tr>
<td></td>
<td>Cohort 1 (n = 27)</td>
<td>Cohort 2 (n = 33)</td>
<td>Combined (n = 60)</td>
</tr>
<tr>
<td>Males</td>
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<td></td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
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<tr>
<td></td>
<td>11 41%</td>
<td>21 64%</td>
<td>32 49%</td>
</tr>
<tr>
<td>Race</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>14 52%</td>
<td>13 39%</td>
<td>27 45%</td>
</tr>
<tr>
<td>White</td>
<td>8 30%</td>
<td>12 36%</td>
<td>20 33%</td>
</tr>
<tr>
<td>Hispanic</td>
<td>4 15%</td>
<td>1 3%</td>
<td>5 8%</td>
</tr>
<tr>
<td>Other</td>
<td>1 4%</td>
<td>7 21%</td>
<td>8 13%</td>
</tr>
<tr>
<td>Reduced/free lunch</td>
<td>23 85%</td>
<td>24 73%</td>
<td>47 72%</td>
</tr>
<tr>
<td>School-identified disability</td>
<td>1 4%</td>
<td>6 18%</td>
<td>7 11%</td>
</tr>
<tr>
<td>English-language learners</td>
<td>2 7%</td>
<td>1 3%</td>
<td>3 5%</td>
</tr>
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</table>

Note. DF + Comp = Decoding fluency combined with reading comprehension treatment; WM + DF + Comp = Decoding fluency treatment combined with comprehension and working memory treatment.
References


