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The Effects of ADHD Treatment and Reading Intervention on the Fluency and Comprehension of Children with ADHD and Word Reading Difficulties: A Randomized Clinical Trial

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Abstract

Many students with reading difficulties and disabilities (RD) also have Attention Deficit/Hyperactivity Disorder (ADHD). This randomized clinical trial compared the effects of ADHD treatment alone (medication, parent training), intensive reading intervention alone, and their combination on the reading fluency and comprehension of students with both disorders. Students with ADHD and RD were randomly assigned to receive (a) Reading Intervention only (n=74), (b) ADHD Treatment only (n=78), or (c) simultaneous Combined ADHD and RD Treatment (n=70). For phonemic decoding fluency, the Reading Intervention group and the Combined Treatment group both had significantly better outcomes than the ADHD Treatment group, but did not differ from one another. For passage comprehension, the ADHD Treatment group had significantly better outcomes than the Reading Intervention group, while the other groups did not differ from one another. ADHD treatment may support passage comprehension in this population, while fluent decoding is best supported through intensive reading intervention.

Many children with reading difficulties and disabilities also have attention-deficit/hyperactivity disorder (ADHD; Boada, Willcutt, & Pennington, 2012; Wei, Yu, & Shaver, 2014). Students who have a reading disorder and ADHD have more severe academic and social difficulties and more negative long-term life consequences than students with either disorder alone (Boada et al., 2012; Purvis & Tannock, 2000; Rucklidge & Tannock, 2002;

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Seidman, Biederman, Monuteaux, Doyle, & Faraone, 2001; Wei et al., 2014; Willcutt et al., 2007; 2010; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Although students with reading disorders and ADHD comprise a particularly at-risk population, effective intervention strategies for these students are poorly understood.

The purpose of this randomized clinical trial (RCT) was to compare the effects on ADHD symptoms and reading outcomes of providing students who have significant word reading difficulties or disabilities and ADHD with ADHD treatment, intensive reading intervention, or simultaneous reading intervention and ADHD treatment. This paper reports on secondary reading outcomes for the study, which primarily examined the effects of ADHD treatment, reading intervention, and their combination on ADHD symptoms, word reading, and phonological decoding. These primary study outcomes were publicly registered a priori on clinicaltrials.gov (#NCT01133847). Like most large RCTs, this study included a comprehensive and broad range of assessments to assess treatment outcomes. Since the RCT was assessing reading as well as ADHD outcomes, the assessment battery was quite extensive and included multiple methods and multiple informants. Selecting primary study outcomes a priori is common in clinical trials, and allowed us to power the study for those primary outcomes. Secondary reading outcomes are addressed in the current paper, and subsequent papers will describe secondary outcomes related to ADHD symptoms and functioning. Results from the primary outcomes paper indicated that students who received reading intervention, either alone or in combination with ADHD treatment, performed significantly better than those who received only ADHD treatment on both untimed word reading and phonological decoding (Tamm et al., 2017). There was no added advantage of combined ADHD treatment and reading intervention beyond reading intervention alone for those outcomes. Similarly, ADHD symptoms (i.e., inattention, hyperactivity/impulsivity) were significantly more improved in the groups that received ADHD treatment, either alone or combined with reading intervention, than in the group that received reading intervention alone. There was no added advantage of combining ADHD treatment with reading intervention for the reduction of inattention or hyperactivity/impulsivity (Tamm et al., 2017). Thus, for the primary study outcomes, the ADHD treatment appeared to have acted on ADHD symptoms, and the reading intervention appeared to have affected the reading difficulties; there did not seem to be an enhanced effect from combining the two treatments.

Fluency and Comprehension Difficulties in Students with ADHD

Students with ADHD are frequently impaired in reading fluency (Ghelani et al., 2004; Jacobson et al., 2011; Jacobson, Ryan, Denckla, Mostofsky, & Mahone, 2013) and comprehension (Ghelani et al., 2004; Martinussen & Mackenzie, 2015; Miller et al., 2013; Stern & Shalev, 2013; Willcutt et al., 2007). In addition to word reading problems, low fluency in students with ADHD has been related to limitations in sustained attention (Jacobson et al., 2013; Tamm et al., 2014), processing speed (Jacobson et al., 2011), and verbal working memory (Jacobson et al., 2011). Comprehension difficulties in children with ADHD are associated with impairments in sustained attention (Stern & Shalev, 2013), working memory (Miller et al., 2013), and other executive functions.

Although some have found that processing impairments associated with ADHD impact reading comprehension through their primary impact on word reading (Martinussen & Mackenzie, 2015; Tamm et al., 2014), there is also evidence of impaired linguistic comprehension in these students. Miller et al. (2013) reported that students with ADHD have difficulty recalling ideas that are central to the meaning of a text, even after controlling for word reading. In addition, children with ADHD have demonstrated lower sensitivity to cause-effect relationships than typically-developing children (Lorch et al., 1999; 2004; Van Neste, Hayden, Lorch, & Milich, 2015), as well as difficulties with making inferences and monitoring comprehension in orally-presented narratives (Berthiaume, Lorch, & Milich, 2010; Van Neste et al., 2015). Children with ADHD also have problems producing organized verbal retellings of narratives that are read to them or illustrated in wordless picture books (Flory et al., 2006; Luo & Timler, 2008; Renz et al., 2003; Tannock, Purvis, & Schachar, 1993).

Interventions for Students with ADHD and Word Reading Difficulties

Reading interventions.

There is converging evidence of the positive effects of instructional reading interventions for students with or at-risk of reading difficulties in the elementary grades (Wanzek, Wexler, Vaughn, & Ciullo, 2010; Wanzek et al., 2013; 2018), even for students with significant word reading difficulties (Fletcher, Lyon, Fuchs, & Barnes, 2019; Torgesen, 2006). A review by Fletcher et al. (2019) concluded that effective interventions for students with word reading difficulties include direct, explicit instruction in phonics, integrated with instruction in word recognition, spelling, reading fluency, and comprehension. Effective interventions for students with dyslexia and other word reading difficulties are systematic and structured, with necessary subskills taught before more complex skills are introduced (Spear-Swerling, 2019). Less is known about effective reading interventions for students with ADHD (DuPaul & Weyandt, 2006). Computer assisted instruction has demonstrated positive effects on reading in inattentive students and students with identified ADHD (Clarfield & Stoner, 2005; Deault, Savage, & Abrami, 2009; Rabiner, Murray, Skinner, & Malone, 2010; Walcott, Marett, & Hessel, 2014). Peer tutoring has been associated with positive effects on engagement and task completion (DuPaul & Weyandt, 2006); however, Dion et al. (2011) found no effects on reading fluency or comprehension for inattentive first graders who received peer tutoring. In general, there is evidence that attentional difficulties contribute to weakened response to reading interventions (Nelson, Benner, & Gonzalez, 2003; Rabiner, Malone, and Conduct Problems Prevention Research Group, 2004).

ADHD treatment.

Guidelines from the American Academy of Child and Adolescent Psychiatry (2007) recommend combining pharmacological and behavioral interventions for children with ADHD. Considerable evidence documents the effectiveness of ADHD medications for the reduction of ADHD symptoms and improved functioning (Sibley, Kuriyan, Evans, Waxmonsky, & Smith, 2014). Pharmacological treatment provided to children with ADHD without accompanying reading intervention has been associated with improved word reading in several studies (Bental & Tirosh, 2008; Keulers et al., 2007; Shaywitz, Williams, Fox, &

Wietecha, 2014; Sumner et al., 2009; Williamson, Murray, Damaraju, Ascher, & Starr, 2014). Findings have been mixed regarding the effects of ADHD medications on reading fluency and comprehension in children with ADHD symptoms. Forness, Cantwell, Swanson, Hanna, and Youpa (1991) reported a significant effect of methylphenidate on both fluency and comprehension for boys with hyperactivity and conduct disorder; however, in a second study with the same population, no significant effects of methylphenidate on either fluency or comprehension were found (Forness, Swanson, Cantwell, Youpa, & Hanna, 1992). Similarly, Keulers et al. (2007) reported no significant pretest-posttest standard score differences on word reading fluency associated with methylphenidate for children with reading disorders and ADHD, while, in a randomized placebo-controlled study, Williamson et al. (2014) reported significant beneficial effects of methylphenidate on text reading fluency for children with ADHD, with or without accompanying reading disorders. Williamson et al. (2014) found that students with ADHD alone had significantly improved reading comprehension with methylphenidate, but this was not true for those with ADHD and word reading difficulties. Mixed results have also been reported for the impact of atomoxetine for adolescents with ADHD and reading disorders. Atomoxetine has been associated with significant growth in reading comprehension for this population (Sumner et al., 2009); however, Shaywitz et al. (2017) found no significant differences on reading fluency or comprehension in an evaluation of atomoxetine vs. placebo.

Behavioral interventions have been associated with improvements in ADHD symptoms and functioning (Evans et al., 2014), but relatively little is known about the effects of behavioral ADHD interventions on reading. A systematic review of research on psychosocial treatments for ADHD included only two studies that reported outcomes on standardized reading measures, and both reported negligible or negative effects (Evans et al., 2014).

Combined ADHD and Word Reading Difficulties treatment.

Two studies have examined the effects on reading comprehension of providing ADHD medication concurrently with reading interventions for children with reading disorders and ADHD symptoms. Richardson, Kupietz, Winsberg, Maitinsky, and Mendell (1988) assessed the impact of providing methylphenidate or placebo in addition to reading intervention to 45 hyperactive children with reading disorders, reporting no significant effects of methylphenidate on comprehension. Students in this study saw reading interventionists once per week, and it is not known whether combining methylphenidate with a more intensive reading intervention would have produced different outcomes. In the second study, Tannock et al. (2018) examined the impact of combining reading intervention with methylphenidate for children with reading disorders and ADHD. Participants were randomly assigned to receive methylphenidate or placebo in conjunction with one of three instructional conditions (one of which was unrelated to reading instruction). Due to small sample size, the researchers analyzed the effects of methylphenidate vs. placebo for a collapsed sample of students who received any of the three academic programs ($n = 34$ methylphenidate, 31 placebo), reporting no significant effects of methylphenidate on reading comprehension. Since the analysis sample included both students who did and did not receive reading intervention, this study does not provide a true test of the added value of methylphenidate to reading intervention alone.

Research Questions

The purpose of this study was to evaluate the effectiveness of three treatment strategies for elementary school students with significant word reading difficulties and ADHD: (a) ADHD treatment alone, (b) reading intervention alone, and (c) simultaneous ADHD treatment and reading intervention. In the current paper, we address the following research questions: (a) Is reading intervention alone more effective than ADHD treatment alone for improved reading fluency and reading comprehension? and (b) Is providing ADHD treatment concurrently with reading intervention more effective than providing only reading intervention or only ADHD treatment for improved reading fluency and comprehension?

There is converging evidence of the effectiveness of intensive, phonologically-based interventions for students with word reading difficulties (Fletcher et al., 2019). Thus, we hypothesized that intensive reading intervention would be associated with better reading outcomes than providing only ADHD treatment for students with ADHD and word reading difficulties. However, we expected that the effects of reading interventions for students with ADHD and word reading difficulties could be strengthened by alleviating their attentional difficulties through simultaneous ADHD treatment. Pelham and Waschbusch, (1999) theorized that combined pharmacological and behavioral interventions for children with ADHD would have either additive effects or complementary effects. Additive effects are synergistic, so that the combination of treatments is more powerful than either individual treatment. Complementary effects impact different symptoms so that the combination of treatments affects a wider array of symptoms than the individual treatments. We hypothesized that simultaneously providing both ADHD treatment and reading intervention to students with ADHD and word reading difficulties would have an additive effect on reading outcomes since reducing ADHD symptoms could increase students' time on task, task persistence, and cognitive engagement with reading instruction. Thus, we expected the combined treatment to be more effective than reading intervention alone.

Method

This study was conducted in accordance with US Federal Policy for the Protection of Human Subjects and was approved by the institutional review boards of the University of Texas Health Science Center at Houston, Cincinnati Children's Hospital Medical Center, and Florida State University. Written informed parental consent and child assent to participate were obtained for all study participants.

Participants

This study was implemented with children from 63 schools in two urban centers in the southern and mid-western United States. The study was replicated with seven cohorts of students from 2011–2015 to build the requisite sample size. Participants were in grades 2 to 5 and had ADHD and word reading difficulties. Initial eligibility screening consisted of the inattention items from the Swanson Nolan and Pelham-IV (SNAP-IV; Swanson, 1992) rating scale, completed by parents and teachers. Parents of children who were taking ADHD medication at the time of screening rated their children's inattention while on the medication; to be evaluated further for the study, children had to demonstrate inattentive

symptoms even when taking their current medications. Other inclusionary criteria were: (a) a standard score $\geq 25^{\text{th}}$ percentile on either the Woodcock-Johnson III (WJ-III; Woodcock, McGrew, & Mather, 2001) Letter-Word Identification or Word Attack subtests or the Basic Reading Skills composite and (b) meeting DSM-IV diagnostic criteria for ADHD (Combined or Inattentive type) based on the Diagnostic Interview Schedule for Children, 4.0 (DISC-4; Shaffer, Fisher, Lucas, Dulcan, & Schwab-Stone, 2000) or meeting the criteria based on endorsement of non-overlapping symptoms by parents on the DISC-4 and teachers on the SNAP-IV (MTA Cooperative Group, 1999). Exclusionary criteria were (a) full scale or nonverbal IQ < 70 ; (b) severe psychopathology, autism, or uncorrected serious sensory disability; (c) receiving primary reading instruction in a language other than English or having parents who were non-English-speakers (parent training was only available in English); (d) medical contraindications for stimulant medication; and (e) taking a psychotropic medication that could impact ADHD. In all, 2,239 children were assessed for eligibility (see Figure 1).

The study was powered to detect pairwise differences among the groups, which guaranteed enough power to detect a difference among the groups on the omnibus test (Kraemer & Thiemann, 1987) taking into account potential site and site by treatment interactions (Kraemer, 2000; Kraemer & Robinson, 2005). A total of 222 students were randomly assigned, stratified by grade, to receive: (a) reading intervention alone (Reading Intervention Group; $n=74$), (b) ADHD treatment alone (ADHD Treatment Group; $n=78$), or (c) simultaneous reading intervention and ADHD treatment (Combined Treatment Group; $n=70$) (see Figure 1). We did not include an untreated comparison group, as previous studies have demonstrated that intervention approaches used to treat ADHD and word reading difficulties in the current study are superior to community treatment (MTA Cooperative Group 1999; Torgesen, 2006). Participants were enrolled by the first and second authors and their teams at the two research sites, while randomization and assignment of participants to interventions were conducted by the third author, the study methodologist, located at a different site. Randomization occurred at the child level and was blocked by site, cohort, and school in sets of six to prevent the ability of the team to guess the next assignment. Random allocation occurred via sequentially numbered envelopes maintained in a locked cabinet and only opened at randomization.

Nine students withdrew during the study, and an additional nine had both pretest and posttest data but did not receive their assigned interventions. These 18 students were retained in the analyses. Prior to analysis it was found that six students were actually ineligible for the study (one in the Reading Intervention Group, one in the ADHD Treatment Group, and four in Combined Treatment Group). These students were excluded, resulting in an analysis sample of 216 (see Figure 1).

Students were predominantly African American and economically disadvantaged (Table 1). Parents reported that from 35% to 42% of the students were served by special education, primarily due to speech and language disorders, learning disabilities, and behavior disorders. Although inclusion in the study was based on word reading or decoding scores $\geq 25^{\text{th}}$ percentile, as a group the participants were severely impaired word readers, with group mean

baseline scores in word reading and decoding ranging from the 3rd to 5th percentiles (Table 1).

Measures

Word reading fluency and phonemic decoding fluency were measured using the Test of Word Reading Efficiency (TOWRE; Torgesen, Wagner & Rashotte, 1999). Sight Word Efficiency measures the fluent reading of words, and Phonemic Decoding Efficiency measures the fluent decoding of nonsense words that follow English spelling rules. Torgesen et al. (1999) report alternate form reliability from .91-.97 for the TOWRE subtests at ages 7–11. Oral reading fluency in connected text was measured with the Dynamic Indicators of Basic Early Literacy Skills (DIBELS; Good & Kaminski, 2002) Oral Reading Fluency subtest. In DIBELS Oral Reading Fluency, students read passages orally, and the score is the number of words read correctly in one minute. In this study, students read two grade-level DIBELS passages, and the dependent variable was the mean score for the two passages. Reliability for DIBELS Oral Reading Fluency exceeds .80 (Goffreda & DiPerna, 2010). Silent sentence-reading efficiency (i.e., both fluency and comprehension) was measured with a prepublication version of the Test of Silent Reading Efficiency and Comprehension (TOSREC; Wagner et al., 2010). In the TOSREC, students are given a list of sentences and have three minutes to indicate whether the sentences are true or false, based on their background knowledge. On the published TOSREC, alternate form reliability ranges from .84 to .95 at grades 2–5. Passage comprehension was measured using the Reading Comprehension subtest of the Wechsler Individual Achievement Test-3 (WIAT-3; Wechsler, 2009). In WIAT-3 Reading Comprehension, the students read passages silently or orally and answer literal and inferential comprehension questions about them. Reliability coefficients for WIAT-3 Reading Comprehension for grades 2–5 range from .79 to .91.

Procedures

Students were assessed at pretest and posttest in the researchers' offices or in the schools by un-blinded research assistants who were trained to reliability criteria. Students taking ADHD medications at enrollment did not take those medications during the pretest. Randomization occurred after pretesting. Participants received 16 weeks of treatment, excluding week-long school holidays (students on medication remained on medication during the breaks). Students in the ADHD treatment and combined treatment groups completed the posttest while on study medications.

Reading intervention.—Reading intervention was provided individually or in groups of two students by tutors who were part of the research team. Intervention was provided to students in the Reading Intervention and Combined Treatment Groups in 45-minute lessons, four days per week. About 87% of the students in the Reading Intervention Group received intervention individually, while 13% received intervention in groups of two. About 81% of the students in the Combined Treatment Group received one-on-one reading intervention, while 19% received intervention in groups of two. Of the 14 pairs of students who received reading intervention together, 9 pairs included students from different treatment assignments (i.e., one student from the Reading Intervention Group and one student from the Combined Treatment Group). Over 16 weeks, a total of 64 lessons were possible. Interventionists

attended a four-day initial training provided by the first author and site-based reading specialists, followed by ongoing coaching from the reading specialists. Returning interventionists received two days of training and ongoing coaching in subsequent years.

Since participants were recruited based on word reading difficulties, the reading intervention focused primarily on phonemic decoding, structural (morphemic) analysis in multi-syllable words, recognition of high-frequency words, and spelling. All students received this word-level instruction throughout the study. When students met criteria for reading on at least a second-grade level, instruction in fluency and comprehension was added and word-level instruction was decreased to maintain the 45-minute lesson.

Tutors provided explicit, systematic instruction in phonics, structural analysis, word-reading, and spelling using two programs: *Sound Partners* (Vadasy & Sanders, 2007) and *Sound Partners Plus* multisyllabic word lessons (Vadasy et al., 2005), supplemented with hands-on practice activities with manipulatives (e.g., letter tiles). Students read decodable texts associated with the phonics programs, and they read motivating non-decodable texts with tutor support. Fluency instruction consisted of repeated reading practice using expository text from *Quick Reads* (Hiebert, 2003). Comprehension instruction was integrated into the fluency practice routine and addressed the strategies of predicting, paraphrasing, and identifying main ideas. Specifically, tutors and students followed a routine with each *Quick Reads* passage: (a) students predicted what they would learn in the passage based on text features; (b) students read the passage while being timed for fluency (c) tutors modeled a reading comprehension strategy; (c) students reread the passage while applying the comprehension strategy with teacher scaffolding and feedback; (d) students verified whether their pre-reading predictions were correct; (e) students reread the passage orally two to three times to build fluency; and (f) students read the passage again while being timed to determine whether their fluency goals had been met.

Treatment fidelity was evaluated for each interventionist at least three times per year by site reading specialists, who coded video-recorded lessons. To support cross-site implementation consistency, each reading specialist coded the videos of the interventionists from the opposite site. The reading specialists re-established reliability prior to coding videos of each cohort; their mean agreement was 94% ($SD=2\%$). Fidelity was rated using an instrument reflecting key characteristics of the intervention. Tutors were rated on instructional characteristics (e.g., implementing activities as described in the teacher's manual; providing accurate explicit modeling and clear explanation; providing appropriate error correction; keeping students on-task) on a three-point Likert scale. A rating was calculated for each observation as a percentage of a possible perfect score. The mean fidelity rating across cohorts and tutors was 95% ($SD=3\%$).

ADHD treatment.—Students assigned to the ADHD Treatment and Combined Treatment Groups received ADHD treatment, which included behavioral parent training and ADHD medication. Parent training was provided by clinical psychologists in nine group sessions over 10 weeks. Topics included psychoeducation about ADHD and evidence-based strategies for behavior management. Psychologists attended a two-day training led by the

second author. All sessions were audiotaped, and at least two randomly selected sessions per site per cohort were coded for fidelity. The mean fidelity rating was 99% ($SD = 2.2\%$).

Students in the two groups assigned to received ADHD treatment were provided with open-label ADHD medications by physicians who were part of the research team. Treatment typically began with a low dose of extended release methylphenidate (Concerta), which was titrated up in weekly visits to a dosage at which the child had satisfactory response with limited side effects. Weekly ratings of ADHD symptoms and medication side effects were obtained from parents and teachers and were used by physicians to inform changes in dosages or medications. If a child did not respond to methylphenidate or had intolerable side effects, treatment with a low dose of mixed amphetamine salts (Adderall) was begun and titrated up until an optimal dose was identified. If neither stimulant provided an acceptable result, a trial with the non-stimulants atomoxetine (Strattera) or extended-release guanfacine (Intuniv) was initiated. When children reached an optimal dose of well-tolerated medication, treatment continued at that dose with monthly monitoring visits for the duration of the study.

Analytic approach

All analyses were conducted using an intent to treat approach (Montori & Guyatt, 2001); data from all participants were retained in the analyses with the exception of the six students who did not meet inclusion criteria (see Figure 1). In preliminary analyses we investigated whether the three groups differed on initial reading ability and baseline demographic characteristics using one-way analyses of variance (ANOVA) and chi-square tests. We also computed Pearson's correlations between the various outcome measures. To estimate treatment effects for the three treatment groups, we utilized analysis of covariance (ANCOVA) controlling for pre-test scores, using maximum likelihood to address missing data (Enders, 2010). Significant main effects were followed up with post-hoc contrasts comparing estimated marginal means at post-test between the three treatment groups. The p values from these post-hoc analyses were corrected for multiple comparisons using procedures described by Benjamini and Hochberg (1995); we report corrected p values. We computed Hedges g as an estimate of effect size (Cohen, 1992). We used the same approach for analyses examining potential interactions with sex, site, and cohort.

To investigate the effects of treatment adherence we computed difference scores (post-test minus pretest) for each outcome and correlated those scores with the relevant adherence metric (i.e., Reading Intervention Group: number of reading sessions attended; ADHD Treatment Group: number of parent training sessions attended and proportion of days children had available study medication to take; Combined Treatment Group: all three adherence variables).

Every effort was made to keep participants in the treatment to which they were randomly assigned. However, according to parent report, some students received interventions associated with other conditions (e.g., some students assigned to the Reading Intervention Group received ADHD medications from non-study physicians). We performed a sensitivity analysis by re-analyzing the data after removing these students to investigate whether the pattern of significant findings changed.

RESULTS

Preliminary Analyses

The three treatment groups did not differ on baseline demographic characteristics with the exception of sex (Table 1); the Combined Treatment Group had fewer boys. There was also a main effect of sex on the TOSREC, and sex interacted with treatment condition to predict outcome on the TOSREC. Therefore sex and the sex*treatment interaction were included in the analyses. Neither site nor cohort interacted with treatment group on any of the reading outcomes. There were no significant differences between the three treatment groups on any pretest scores on the fluency or comprehension assessments. There were no significant effects for group size (one-on-one vs. groups of two). Table 2 illustrates the correlations among the measures at posttest.

Treatment Effects

We observed statistically significant differences for treatment group on TOWRE Phonemic Decoding Efficiency and WIAT-3 Reading Comprehension (Table 3). Follow-up tests on TOWRE Phonemic Decoding Efficiency, controlling for pretest scores, indicated that the Reading Intervention Group, $t(202)=2.74$, $p=.007$, $g=.34$ [.09-.58, 95% confidence interval (CI)] and Combined Treatment Group, $t(202)=2.19$, $p=.03$, $g=.28$ [.02-.53, 95% CI] had significantly higher posttest means than the ADHD Treatment Group. The Reading Intervention and Combined Treatment Groups were not statistically different from each other. Following up the main effect of treatment for the WIAT-3 Reading Comprehension posttest means, after controlling for pretest scores, a statistically significant difference was observed between the ADHD Treatment and Reading Intervention groups, in favor of the ADHD Treatment Group, $t(203)=2.70$, $p=.008$, $g=.30$ [.08-.53, 95% CI].

In addition to the two main effects previously described, a significant interaction between treatment and sex was observed in the analysis of the TOSREC. Post-hoc tests revealed a statistically significant difference favoring girls over boys in the Combined Treatment Group, $t(198)=3.89$, $p=.0001$, $\text{mean}_{(\text{boys})}=15.2$, $\text{mean}_{(\text{girls})}=21.1$, $g=.73$ [.33-1.13, 95% CI].

Treatment adherence.—Of the possible 64 reading intervention lessons, students in the Reading Intervention Group attended an average of 56 lessons ($SD=11$), and students in the Combined Treatment Group attended an average of 55 lessons ($SD=14$). Parents of students in both the ADHD Treatment and Combined Treatment Groups attended an average of five of the nine parent training sessions ($SD=3$ for each group). Medication adherence (i.e., proportion of days children had available study medication to take) was 74% in the ADHD Treatment Group ($SD=35\%$) and 80% in the Combined Treatment Group ($SD=32\%$). Neither reading intervention attendance, parent training attendance, nor medication adherence differed significantly between treatment groups.

For the ADHD Treatment Group, both medication adherence ($r=.28$, $p=.02$) and attendance at parent training sessions ($r=.31$, $p=.009$) were positively associated with growth on TOWRE Phonemic Decoding Efficiency. The correlations of adherence variables with the other four change scores were nonsignificant. Medication adherence was also positively

correlated with growth in TOWRE Phonemic Decoding Efficiency for the Combined Treatment Group ($r=.28$, $p=.03$). No other significant correlations were found for the Combined Treatment Group. For the Reading Intervention Group, attendance at reading lessons was not significantly associated with any of the five change scores.

Crossover analysis.—At posttest, parents of 22.5% of the students assigned to the Reading Intervention Group reported that their children had taken ADHD medication provided by a non-study physician at some point during the study; 4.1% of these parents had attended some form of parent training. At posttest, parents of 17.1% and 6.1% of students assigned to the ADHD Treatment and Combined Treatment Groups, respectively, reported that their children no longer took the study medications. In addition, teachers reported that 31.5% of students in the Reading Intervention, 36.4% in the ADHD Treatment, and 28.8% in the Combined Treatment Groups received supplemental reading intervention from a special educator or reading interventionist at some point in the study in addition to the study treatments; these proportions did not differ between groups [$\chi^2(2)=1.181$, $p=.56$]. Sensitivity analyses to evaluate the impact of participants who received treatments to which they were not randomly assigned revealed that the pattern of results for the outcomes were identical to analyses performed upon the full sample.

DISCUSSION

This study examined the relative effects on the reading fluency and comprehension of students with ADHD and word reading difficulties of providing intensive reading intervention alone, ADHD treatment alone, and simultaneous combined reading intervention and ADHD treatment. We hypothesized that reading intervention would produce better reading outcomes than ADHD treatment alone, and that combining the reading and ADHD treatments would have an additive, synergistic effect (Pelham & Waschbusch, 1999), making simultaneous ADHD treatment and reading intervention more effective than reading intervention alone.

With regard to reading fluency, our hypothesis that reading intervention would be associated with better outcomes than ADHD treatment alone was partially supported. Outcomes for phonemic decoding fluency were significantly better for students who received reading intervention, either alone or in combination with ADHD treatment, than for those who received only ADHD treatment. Effect sizes for both groups were educationally meaningful ($g=.28$ to $.34$; US Department of Education, 2018). There was no difference between outcomes for students in the Combined Treatment and Reading Intervention Groups. Thus, for supporting fluent decoding, intensive reading intervention was more effective than ADHD treatment, and there was no added value of providing ADHD treatment in addition to the reading intervention. This finding parallels those reported for the same group of students for untimed phonemic decoding, for which students who received only reading intervention and students who received combined reading and ADHD treatment both performed significantly better than those who received only ADHD treatment, and there was no value of adding ADHD treatment to reading intervention (Tamm et al., 2017).

Significant positive correlations were found between adherence to the ADHD treatment and growth in phonemic decoding fluency in the ADHD Treatment and Combined Treatment Groups. This may be indicative of some contribution of ADHD treatment to this domain; however, Table 3 indicates that, on average, pretest and posttest standard scores did not differ on this variable for students in ADHD Treatment.

No significant group differences were observed for sight word fluency or text reading fluency. Students who received reading intervention in either Reading Intervention or Combined Treatment Groups improved on both of these measures from pretest to posttest, while those in the ADHD Treatment Group did not. Tamm et al. (2017) reported significant effects for untimed word reading favoring the two groups who received reading intervention over the group that only received ADHD treatment. The finding that fluency is more resistant to remediation than word reading has been previously reported in intervention studies with students who have significant word reading difficulties (e.g., Torgesen et al., 2001). The difficulty of remediating fluency is likely related to the large deficit in text reading experience for students with significant reading difficulties, which limits their exposure to words and in turn their automaticity of word recognition (Torgesen & Hudson, 2006). In the current study, 16 weeks of intervention was insufficient to build automaticity for students with significant word reading difficulties.

There were also no significant group differences observed on the TOSREC silent reading efficiency measure; however, a significant interaction with sex was found in the Combined Treatment Group, where girls made significantly greater gains than boys. The effect size for this interaction was large ($g = .79$). Mano et al. (2017) reported that, in a group of children with ADHD and reading difficulties, girls with more externalizing behavior problems had lower reading comprehension scores, while the same effect was not observed for boys. In the current study, it is possible that girls assigned to combined treatment were able to benefit more from reading intervention due to positive effects on externalizing behavior problems associated with concurrent ADHD treatment. It is not known why this effect was seen only on the TOSREC. More research on gender differences in the effects of ADHD treatment on reading fluency and comprehension is warranted.

Significant group differences were found for passage comprehension on WIAT-3 Reading Comprehension. Our hypotheses were not supported for this outcome; students who received only the ADHD Treatment performed significantly better than those who received only Reading Intervention. Table 3 illustrates that students in all three groups improved on WIAT-3 Reading Comprehension from pretest to posttest. Students in the ADHD Treatment Group outperformed those in the Combined Treatment Group, who outperformed those who only received reading intervention; however, only the difference between ADHD Treatment and Reading Intervention Groups was statistically significant.

The enhanced comprehension of students who received ADHD treatment is likely related to the effects of ADHD medications on executive functions in these students. Cognitive flexibility (i.e., shifting), planning, inhibition, and working memory have been consistently related to reading comprehension (Follmer, 2018), and stimulant medication has been shown to positively impact cognitive flexibility, planning, and inhibition in children with ADHD

(Pietrzak, Mollica, Maruff, & Snyder, 2006; Tamminga, Reneman, Huizenga, & Geurts, 2016). Evidence of effects on working memory is mixed (Pietrzak et al., 2006) and varies depending on how working memory is measured (Bedard, Jain, Hogg-Johnson, & Tannock, 2007). Thus, it is feasible that providing ADHD medication to students with ADHD and word reading difficulties may enhance critical text processes through its effects on executive functions. It is also possible that the parent training component offered in combination with medication supported students' development of self-regulation, enhancing attention to text passages and supporting comprehension. Improvements in comprehension may have also been related to growth in reading fluency; however, the three groups did not differ in their growth in oral text reading fluency, and the ADHD Treatment Group made the smallest gains in this domain.

The relatively weak effect of reading intervention on reading comprehension was unexpected; however, since participants qualified for the study on the basis of word reading and decoding impairments the reading intervention focused primarily on word-level skills. Comprehension instruction was of relatively low intensity and addressed only the strategies of prediction, paraphrasing, and identifying main ideas in text. Students received fluency and comprehension instruction only when they could read on at least a second-grade level. An extended intervention with a greater focus on comprehension may be required to support comprehension in students with significant word reading difficulties and ADHD, particularly since inattentive students are more resistant to reading remediation (Nelson, et al., 2003; Rabiner et al., 2004).

Limitations

Most of the participants in this study were low income African American children. This may limit generalizability to other populations; however, it informs the field about the treatment of ADHD and word reading difficulties for an understudied group of students. It should also be noted that participants were, on average, severely impaired word readers. Results may have differed if we had included students with less severe impairments. Additionally, we did not include an untreated control group. For word and text reading fluency and sentence reading efficiency, for which we found no significant group differences, it is not known whether all three treatment strategies were effective or ineffective relative to no treatment at all. Although we had measures in place to promote treatment adherence, there was some cross-over and non-adherence. This may have limited our ability to detect treatment effects; however, the intent-to-treat analysis permits generalization to populations with less than perfect adherence. Finally, research assistants who administered posttest assessments were not blind to participants' assigned conditions; however, these examiners underwent rigorous training on the highly standardized administration procedures for the measures. Further, our mixed results on tests of word reading, fluency, and comprehension make it seem unlikely that the examiners were biased toward any one group.

Theoretical Implications

We had hypothesized that combining reading and ADHD treatments would have an additive, synergistic effect (Pelham & Waschbusch, 1999), making the combined treatment more effective than reading intervention alone. We expected that removing the barrier of chronic

inattention through ADHD treatment would increase the effectiveness of intensive reading intervention. Some of the secondary findings in this study may indicate such an additive effect. For example, there was a positive interaction between adherence to the ADHD treatment and growth in phonemic decoding efficiency, and there was an effect of gender on sentence reading efficiency that could be related to the effects of ADHD treatment on girls' externalizing behaviors. However, these observations are preliminary, and more research is needed to verify these patterns. For the most part, our outcomes support a complementary effect of treatments (Pelham & Waschbusch, 1999). Congruent with our findings for the primary study outcomes of ADHD symptoms, word reading, and decoding (Tamm et al., 2017), it appears that the combined treatment did not produce a synergistic effect, but rather affected a wider array of symptoms than either treatment in isolation. ADHD treatment was associated with the reduction of ADHD symptoms (Tamm et al., 2017), and with enhanced text comprehension, while intensive reading intervention was associated with improved word reading and phonological decoding (Tamm et al., 2017), and decoding fluency. In no case was the combined treatment significantly more effective than one of the individual treatments.

Implications for Practice

Providing children who have both ADHD and significant word reading difficulties with ADHD treatment consisting of carefully monitored medication and behavioral parent training may support their comprehension of connected text; however, these students will likely require intensive reading intervention to address their decoding difficulties. Intensive phonologically-based reading intervention is likely to positively affect their ability to fluently decode unknown words, and simultaneously adding ADHD treatment is unlikely to enhance the effects of reading intervention in this domain. In general, providing students who have both reading and attention disorders with 16 weeks of intervention is likely to be insufficient to remediate reading fluency and comprehension. Despite gains, on average, students remained impaired at posttest.

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Figure 1.
CONSORT Diagram

Table 1

Demographic and Clinical Characteristics for the Three Treatment Groups

		Reading Intervention (n=73)	ADHD Treatment (n=77)	Combined Treatment (n=66)	Group Differences
Age in Years		8.8 (1.3)	8.9 (1.4)	8.8 (1.2)	F (2,215) = .27, n.s.
Percent Male		67.1%	67.5%	47%	χ^2 (2) = 8.0 *
Percent Hispanic		7.8%	10.5%	18.3%	χ^2 (2) = 3.50, n.s.
Race	Caucasian	17.8%	18.2%	22.7%	χ^2 (6) = 6.3, n.s.
	African American	76.7%	71.4%	68.2%	
	Biracial	5.5%	9.1%	4.5%	
	Other	0%	1.3%	4.5%	
Grade	2	30.6%	28.9%	30.8%	χ^2 (6) = 0.4, n.s.
	3	26.4%	25.0%	24.6%	
	4	25.0%	25.0%	23.1%	
	5	18.1%	21.1%	21.5%	
Economically Disadvantaged		77.7%	77.9%	72.7%	χ^2 (4) = 1.78, n.s.
ADHD Combined Type ^a		58.3%	57.9%	45.5%	χ^2 (2) = 2.9, n.s.
Served by Special Education		35.6%	35.1%	42.4%	χ^2 (2) = 1.0, n.s.
<u>Baseline Scores</u>		<u>M (SD)</u>	<u>M (SD)</u>	<u>M (SD)</u>	
Full Scale IQ ^b		86.2 (12.1)	86.8 (11.8)	86.7 (11.7)	F (2,215) = .05, n.s.
WIAT-3 Word Reading		75.2 (9.3)	75.4 (8.5)	73.8 (8.8)	F (2,215) = .62, n.s.
WIAT-3 Pseudoword Decoding		75.1 (9.7)	73.4 (9.7)	73.3 (7.3)	F (2,215) = .91, n.s.
SNAP-IV ADHD symptoms ^c		1.9 (0.5)	1.8 (0.5)	1.8 (0.5)	F (2,215) = .28, n.s.

Note:

^a All had ADHD Inattentive Type or Combined Type;^b Kaufman Brief Intelligence Test, 2nd edition;^c Average score for the 18 ADHD symptoms across parent and teacher; WIAT-3 = Wechsler Individual Achievement Test, Third Edition; SNAP-IV = Swanson Nolan and Pelham DSM-IV ADHD symptom rating.* $p < .05$

Table 2

Correlations among Observed Scores at Post-Test

Variables	1	2	3	4	5
1. Test of Word Reading Efficiency Sight Word Efficiency	--				
2. Test of Word Reading Efficiency Phonemic Decoding Efficiency	.66	--			
3. Dynamic Indicators of Basic Early Literacy Skills Oral Reading Fluency	.80	.49	--		
4. Wechsler Individual Achievement Test-III Reading Comprehension	.58	.41	.64	--	
5. Test of Sentence Reading Efficiency and Comprehension	.62	.28	.80	.49	--

Note. All correlations are significant at the 0.01 level (2-tailed).

Table 3

Descriptive Statistics and Treatment Effects

	Pretest M (SD)			Posttest M (SD)			Posttest Treatment Effects
	ADHD Treatment	Reading Intervention	Combined Treatment	ADHD Treatment	Reading Intervention	Combined Treatment	
TOWRE SWE	81.14 (10.00) <i>n</i> =76	80.13 (11.40) <i>n</i> =72	80.45 (12.15) <i>n</i> =66	81.15 (9.53) <i>n</i> =72	82.51 (11.50) <i>n</i> =72	83.35 (12.06) <i>n</i> =63	F (2,202) = 2.84, <i>p</i> = .061
TOWRE PDE	80.13 (7.49) <i>n</i> =76	80.65 (8.79) <i>n</i> =72	79.15 (7.72) <i>n</i> =66	80.49 (8.34) <i>n</i> =72	83.90 (10.28) <i>n</i> =72	82.24 (8.40) <i>n</i> =63	F (2,202) = 4.25, <i>p</i> = .016 * Combined > ADHD Treatment; Reading > ADHD Treatment
DIBELS ORF ^a	44.69 (28.20) <i>n</i> =77	39.90 (28.78) <i>n</i> =73	40.51 (29.45) <i>n</i> =66	53.67 (29.52) <i>n</i> =72	50.71 (31.09) <i>n</i> =72	53.83 (33.11) <i>n</i> =63	F (2,203) = 1.34, <i>p</i> = .263
TOSREC ^b	15.15 (6.47) <i>n</i> =75	14.71 (6.76) <i>n</i> =72	14.65 (7.01) <i>n</i> =66	17.50 (7.43) <i>n</i> =72	17.57 (7.60) <i>n</i> =72	18.41 (9.17) <i>n</i> =63	F (2,199) = 1.59, <i>p</i> = .207; Treatment * Sex, F(2,198)=4.07, <i>p</i> =.019 *
WIAT-3 RC	81.45 (10.22) <i>n</i> =77	80.88 (11.14) <i>n</i> =73	80.77 (11.75) <i>n</i> =66	88.67 (12.15) <i>n</i> =72	84.56 (11.19) <i>n</i> =72	86.06 (12.15) <i>n</i> =63	F (2,203) = 3.64, <i>p</i> = .028 * Reading < ADHD Treatment

Note: Treatment Effects = Effect of treatment controlling for pre-test scores; TOWRE = Test of Word Reading Efficiency; SWE = Sight Word Efficiency; PDE = Phonemic Decoding Efficiency; DIBELS = Dynamic Indicators of Basic Early Literacy Skills; ORF = Oral Reading Fluency; TOSREC = Test of Silent Reading Efficiency and Comprehension; WIAT-3 RC = Wechsler Individual Achievement Test-3 Reading Comprehension; Scores are standard scores (*M*±100; *SD* = 15) unless otherwise noted.

^aScore is the number of words read correctly per minute;

^bScore is the total items correct in 3 minutes.

* *p* < .05