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ABSTRACT

This study investigated the extent to which the presence of EF impairments in children with reading disabilities (RD) influenced their responsiveness to reading intervention. We were interested in whether behavioral or cognitive measurements of EF are stronger predictors of intervention response in RD, and whether each type of measurement adds unique predictive variance. In those with RD, we also investigated whether behavioral and/or cognitive measurements of EF predicted intervention responsiveness above and beyond previously studied predictors, such as language and language-related skills. Given the high comorbidity of RD and attention deficit hyperactivity disorder (ADHD), we also assessed the extent to which executive functioning impairments predicted intervention responsiveness in a subgroup of individuals diagnosed with both disorders. In those with RD + ADHD, we investigated whether or not EF impairments predicted intervention responsiveness above and beyond phonological skills and other ADHD symptoms.

INDEX WORDS: Reading disability, ADHD, Executive functioning

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1 INTRODUCTION

1.1 Consequences of Reading Disabilities

It is estimated that over 40 million adults in the United States are functionally illiterate, despite having received adequate reading instruction (Kirsch & Jenkins, 1993). Limited reading skills in adults is associated with a lower likelihood of obtaining employment, fewer responsibilities in the labor force, and lower community and civic involvement (Kutner et. al, 2007), as well as poorer health status (Weiss et. al, 1992). Every year, roughly 3 million Americans enter adult literacy programs in an attempt to improve their basic reading skills, after having either not received or not responded to effective interventions for developmental dyslexia (DD) or other reading disabilities (RD) as a child. This project is particularly interested in factors that can lead to poor responses to childhood interventions, and that can frequently result in such poor adult outcomes.

Increasingly concerning are the numerous studies documenting the “Matthew Effect” (McNamara, Scissons, & Gutknecth, 2011; Morgan, Farkas, & Hibel, 2008; Sideris, 2011), which shows that those who struggle with early reading have increasing difficulties with reading over time. There are many mechanisms behind this effect. For example, those children who struggle with basic reading skills such as decoding may be exposed to less text than their peers over time. In addition, those who struggle with early reading may have decreased motivation to be involved in reading-related activities, furthering the problem of low text exposure. Finally, difficulty with basic reading skills hinders the ability to develop more advanced vocabulary, text comprehension, and integration skills (Cunningham and Stanovich, 1997).

Due to limited print exposure, those with RD are also likely to underperform across several other academic domains in addition to reading and language. Cunningham and Stanovich (1997) found that reading ability in grade 1 was predictive of exposure to print in grade 11, and that exposure levels further predicted growth in reading comprehension abilities across grade levels. La Paro and Pianta's (2000) meta-analysis found that early pre-reading skills also predicted academic success in later elementary school grades. Several other studies in recent years have confirmed this strong link between early reading skills and achievement across many academic areas (Classens, Duncan, & Engel, 2009; Duncan et al, 2007; Reardon, Valentino, & Shores, 2012).

Without successful intervention, most individuals with reading disabilities (RD) will continue to struggle with reading throughout their lifetimes (Grigg, Donahue, & Dion, 2007; Lyon, 1996;), and will continue to lag behind their peers in terms of academic and vocational success (Murnane, Sawhill, & Snow, 2012; Reardon, Valention, & Shores, 2012). Therefore, helping struggling readers improve their reading skills continues to be of the utmost importance.

1.2 Treatment Resistance in RD

Treatment resistance is a critical issue for intervention research in reading disabilities. While numerous successful interventions for RD have been developed, they are not universally effective for all children or adults. Several individuals who undergo any intervention for RD show limited responses and are typically labeled as "treatment-resistant". The factors that underlie or predict such a limited response to intervention are currently unclear, though various cognitive and environmental factors have been proposed.

1.2.1 Cognitive-Linguistic Characteristics Predictive of Treatment Response

The literature on treatment resistance in RD has focused largely on those cognitive deficits specific to reading and language development. An implicit hypothesis underlying these studies is that the more severe the impairment of the language/reading system, the more resistance there will be to interventions. There is already an extensive literature on the hypothesized neurobiological anomalies and cognitive impairments in DD (for a review, see Peterson & Pennington, 2015). The severities of many of these abnormalities have been proposed as factors delineating those who respond well to intervention from those who respond poorly. Early studies found that impairments in phonological processing (Vellutino et al, 1996) and phoneme manipulation (Hatcher and Hulme, 1999) characterized those who responded less well to intervention. Torgesen, Wagner, Rashotte, Rose, et al (1999) found that phonological abilities were particularly predictive of growth in word-level reading skills in response to intervention. More recent studies have found phonological awareness, rapid letter naming, vocabulary, and sentence imitation skills to be the strongest predictors of whether or not an individual shows significant growth in reading skills following intervention (Fletcher et al, 2011; Al Otaiba and Fuchs 2001; Al Otaiba and Fuchs, 2006).

1.2.2 Other Cognitive Characteristics Predictive of Treatment Response

Although the majority of research on treatment resistance has focused on impairment in language and related mechanisms, there is evidence to suggest that non-language factors and more general cognitive mechanisms may also influence response to intervention in those with RD. For instance, Torgesen, Wagner, Rashotte, Rose, et al (1999) found that phonological abilities were particularly predictive of growth in word-level reading skills, but also found that they were not as predictive of response to intervention as socioeconomic background and ratings of behavior and attention problems in the classroom. Al Otaiba and Fuchs (2001) found that reported behavioral problems characterized unresponsive students, and when combined with phonological awareness, naming speed, vocabulary, and sentence imitation, they together predicted 80% of non-responders (Al Otaiba and Fuchs, 2006).

1.2.3 Potential Role of Executive Functioning Skills in Treatment Response

There is also strong support for the hypothesis that impairments in executive function skills may influence whether an individual responds well to an intervention. Executive functions are a cognitive domain known to be important for the application of a wide range of functions. Executive function has been conceptualized in terms of three core functions. These core functions are: working memory that holds information in mind and manipulates it; inhibition or interference control, which allows for selective response to relevant vs. irrelevant information; and cognitive flexibility, which refers to the ability to adapt behavior based upon changing demands of a task (Diamond & Lee, 2011; Diamond, 2014). The ability to selectively focus and sustain attention may also be conceptualized as a fourth core executive function (Garcia-Madruga, Gomez-Veiga, & Vila, 2016). According to Diamond, higher order executive functions, such as problem solving, strategy selection, and metacognitive skills, are built upon these core EFs. Although most studies have not specifically examined the effects of executive function on response to intervention, there is a large literature suggesting that each of these core EF components are critical to the development of reading skills. Cartwright et al (2012) have reviewed the many aspects of executive functions that are necessary for successful reading skill development. Reading requires cognitive flexibility in order to coordinate sound and meaning, as well as the ability to combine multiple elements and features of a passage. More advanced reading comprehension requires cognitive flexibility, inhibitory control to filter out irrelevant information, and shifting and updating abilities in order to integrate new information with that which was previously read in a given text. Garcia-Madruga et al (2016) described the EF skills necessary for reading in terms of four core EFs. In order to read a complex task, in addition to coordinating information between text and LTM (working memory), one must also inhibit older information (inhibiting/interference control) and discard information that is no longer needed (interference control/working memory). In order to do this, individuals also must be able to sustain their attentional focus and not be redirected towards irrelevant information (focus/sustain attention). In this way, the four "core" EFs interact for successful reading. Garcia-Madruga et al (2016) were also able to show that they could improve reading comprehension performance in elementary school children by exposing them to interventions targeting these processes, further suggesting a strong link between EF and reading skill development.

Several experiments have also found links between performances on cognitive tasks measuring core executive functions and reading skill proficiency. Weak working memory skills have shown associations with impaired reading skills (for a review, see Kudo, Lussier, & Swanson, 2015; Swanson et al, 2009), as have weak inhibition and interference control skills as measured through tasks such as the Stroop Task (Booth et al, 2014; Reiter et al, 2005). More complex cognitive tasks that require different combinations of these rudimentary EFs also show associations with reading skills. For example, performance on sorting tasks, which require the ability to inhibit older information and re-direct attention to relevant information, have been associated with reading skill proficiency (i.e. Engel de Abreu et al, 2014). A large body of literature also supports associations between metacognitive skills, including strategy selection and error-monitoring, and proficient reading (i.e. Cutting et al, 2009; Kohlic-Vehovec et al, 2014). These are complex skills requiring interference control, inhibition of irrelevant information, sustained attention to relevant information, and working memory.

Neurobiological bases for the relationship between reading skills and executive functions have also been proposed. Cartwright (2012) points out that, interestingly, a critical period of increased synaptogenesis and myelination in the prefrontal cortex regions necessary for executive function takes place between the ages of 4 and 5 years old, shortly before most children develop necessary pre-reading skills. It is therefore not surprising that executive function skills have been shown to be a necessary prerequisite for the development of early reading skills in young children (Foy et al, 2013). The importance of executive functions for the development of successful reading is also supported by neuroimaging research. An fMRI study by Horowitz-Kraus, Vannest, Gozdas, and Holland (2014) found that greater involvement of the frontal lobe and parietal lobe regions associated with executive functions was associated with the development of greater reading proficiency.

1.2.4 Operationalizing Executive Function-Two Distinct Methods

A distinction is often made in the literature between EF skills measured with cognitive measures, such as those discussed in the studies mentioned above, and EF skills measured with behavior rating scales, such as the Behavior Rating Inventory of Executive Function (BRIEF), typically completed by parents and teachers. These different types of EF measures are not always correlated with one another, possibly due to the fact that different types of measurements reflect the use of executive function skills in different contexts (Ten Eycke and Dewey, 2016; Toplak, West, and Stanovich, 2013). In particular, it has been suggested that behavioral rating scales may measure “typical” day-to-day and “real-world” performance whereas cognitive assessments of EF measure “optimal” performance (Toplak, West, and Stanovich, 2013). Cognitive assessments of EF, assuming optimal effort on the part of the participant, may measure the integrity of a basic cognitive processing system, i.e. the efficiency with which a participant can update an ongoing representation and switch between representations when the task requires it, as on the DKEFS Trails Test. However, even if a cognitive process is functional and can be used to complete a task in a testing session, this does not necessarily mean that the participant can complete related tasks requiring this cognitive process in his/her daily life. A questionnaire such as the BRIEF can provide a measurement of the extent to which a participant successfully completes real-world tasks that may require such cognitive skills. For example, even if an individual is capable of switching between connecting letters and numbers (DKEFS Trails) in a quiet testing room with its implicit structure, this individual may not be able to successfully switch between attending to a written assignment and focusing on a teacher for further instructions in a busy classroom setting. Both cognitive and behaviorally measured EF deficits have been shown to be impaired in those with RD, but rarely have their results been compared within the same subjects and studies. The literature on both cognitive and behavioral executive functioning measures and their impact on reading skills will be discussed below.

It is important to note that the different EFs, or how they are assessed, are not necessarily highly correlated, and have been shown to represent independent factors (Friedman & Miyake, 2017; Miyake et al, 2000; Miyake & Friedman, 2012). Therefore, they have often been studied separately, and the impact of these EFs on response to reading intervention may differ across domains. In the following sections, the literature on different EFs that have been most frequently associated with reading skills is discussed.

1.3. Cognitive Executive Functioning Impairments and RD

Two core EF skills (i.e. working memory and inhibition/interference control) have been considered necessary for reading development. The more severe the EF deficits are, the more resistant the system may be to remediation, leading to a weakened response to any type of intervention for reading skills. The literature on the influences of working memory and interference control on reading skills is discussed below.

1.3.1 Working Memory

Working memory impairment has consistently been identified as a core deficit in RD (for a review, see Kudo et al, 2015; Swanson et al, 2009). A study of Brazilian school children found that those children who were classified by their teachers as “poor readers” due to both poor decoding and comprehension skills showed poorer working memory and poorer cognitive flexibility on a card-sorting task (Engel de Abreu et al, 2014). Dawes et al (2015) also compared a group of struggling readers with poor decoding/basic reading skills to typical readers and found poorer working memory skills in those struggling to read. These working memory deficits were found particularly in the domain of phonological working memory and skills of the central executive, such as ability to mentally manipulate information. Dawes et al (2015) suggested that these working memory impairments may lead to difficulty making appropriate links between graphemes and phonemes, thereby impacting the development of basic reading skills. In a longitudinal study of 84 children, Swanson (2007) found that working memory skills were related to growth in both reading comprehension and reading fluency. Kegel and Bus (2013) used fixed effects analysis to show that longitudinal changes in alphabetic skills are associated with corresponding changes in working memory in kindergarten children.

The effects of working memory have also been investigated in the specific domain of reading comprehension. Swanson et al (2006) suggested that coordinating information between text and long-term memory is necessary for successful reading comprehension. Therefore, those with poor working memory skills may struggle to successfully comprehend text. Cain, Oakhill, and Bryant (2004) found a relationship between working memory abilities and reading comprehension in a longitudinal study of typically developing children, while Caretti et al (2009) found that measures of verbal working memory specifically separated children with good versus poor comprehension skills. DeMagistri, Richards, and Canet Juric (2014) found that working memory skills were weaker in those with poor reading comprehension skills, and that growth in working memory skills was associated with growth in reading comprehension skills. Electrophysiological data has also been used to support the relationship between working memory and reading impairment. Horowitz-Kraus et al (2014) conducted a study that involved collecting ERP data while adolescents with RD performed the Wisconsin Card Sorting Task (WCST). The authors found that, as predicted, those with dyslexia had difficulties maintaining changing set rules in the task and responding promptly. However, they also found that ERP changes in the P300 were weaker in those with dyslexia immediately after the rule on the WCST had just changed, when the demands on working memory had just increased. The authors suggested that this result could imply that difficulty with higher order executive functioning skills needed for successful performance on the WSCT, such as problems with shifting and monitoring tasks might be caused largely by an underlying deficit in working memory that is pervasive in those with dyslexia. It is clear that impairments in the working memory system may have an impact on reading skills and interfere with the ability of the reading system to respond to reading skill intervention.

1.3.2 Inhibition and Interference Control

Impairments in inhibition and interference control are another set of cognitive EF skills that have been associated with both ADHD and RD. Learning to read requires the ability to inhibit irrelevant information and switch attention. Reiter et al (2005) found that those with RD made increased errors on the interference condition of the Stroop Task, indicating weaker inhibitory control abilities, as compared to control participants. Booth et al (2014) also found that cognitive measures of response inhibition ability, including a modified Stroop task, predicted word reading ability.

Longitudinal studies have also shown linkages between inhibitory control and word reading skills. Altemeir et al (2008) found that growth in inhibition skills, as measured through the Color-Word Interference subtest of the DKEFS, was related to growth in literacy outcomes across typically developing children as well as those with dyslexia. DeMagistri, Richards, and Canet Juric (2014) found that inhibition measured through the Hayling Test for inhibition skills were significantly weaker in adolescent readers with poor comprehension skills, and that growth in reading comprehension skills over time is associated with growth in inhibition and working memory skills. Kegel and Bus (2013) used fixed effects analysis to show that longitudinal changes in alphabetic skills are associated with corresponding changes in inhibition skills in kindergarten children. It is clear that inhibitory control skills have a strong influence on reading skills and may therefore influence response to reading skill intervention.

1.3.3 Summary

Inhibitory/Interference control and working memory are aspects of executive functioning that have been shown to contribute strongly to successful reading development. Struggling readers have shown significant impairments compared to their peers on tasks requiring inhibitory/interference control and working memory. Therefore, struggling readers who show greater impairments in these skills may show greater difficulties with remediation of the reading system, and therefore poorer response to intervention. It is suggested that these specific EF skills are predictors of response to reading skill intervention in RD.

1.4 Behavioral Measurements of Executive Functioning Impairments and RD

Unlike cognitive measurements of EF, behavioral questionnaire-based assessments of EF are often thought to measure "typical" rather than "optimal" performance. These measures may provide a more ecologically valid account of how an individual's EF skills affect their daily functioning. Behavioral rating scale measurements and cognitive measurements of EF provide different data about an individual's executive functioning. Rather than cognitive tasks, behavioral ratings of executive function typically consist of questionnaires that are completed by parents and teachers of individuals with suspected executive dysfunction. Questions are aimed at understanding how an individual functions in real-world situations reliant upon different EFs, i.e. whether a child needs to have questions repeated multiple times due to poor working memory, or whether a child frequently fails to monitor his/her work for mistakes. Constructs measured by these scales are reliant upon combinations of many different executive functioning skills. For instance, successful task monitoring, a construct frequently measured in behavioral EF questionnaires, requires the ability to inhibit extraneous stimuli, shift responses accordingly based on successes and failures, and keep track of one’s progress. When an individual shows a weakness in a behaviorally assessed EF domain such as task monitoring, it is not necessarily clear which specific cognitive function is responsible for the measured deficit. Therefore, these measures may not show the same level of discriminant validity as cognitive measurements of EF. However, their ecological validity may be greater, as they allow for a clearer picture of how these EF skills operate together in the real world.

The Behavior Rating Inventory of Executive Function (BRIEF) is one of the most commonly used rating scales used to measure typical, pragmatic performance of executive functioning skills in daily life. The BRIEF is broadly organized into two indices of “typical” EF performance, one measuring behavioral regulation (Behavioral Regulation Index or BRI) and one measuring metacognition (Metacognition Index or MI). The BRI is thought to broadly represent adequacy of skills needed to regulate behavior and emotional responses, whereas the MI is thought to represent the adequacy of skills needed to cognitively manage attention and problem solving (Gioia et al, 1996). Both of these broad domains of EF (metacognition and behavior regulation) are likely to influence the ability to acquire reading skills, and in turn influence response to reading skill intervention. As discussed previously, many cognitively measured EF skills have been shown to influence response to intervention, and these cognitive skills are necessary in part for successful skills in metacognition and behavioral regulation. Therefore, it is likely that behaviorally measured EFs predict response to reading intervention partially due to their shared variance with cognitive measures of EF impairments that affect response to intervention. However, given that past research has indicated that behavioral and cognitive EF measurements are at least partially independent (i.e. Toplak et al, 2013), behavioral measures of EF may also contribute some unique variance in predicting reading skills and response to intervention. In other words, there may be factors that influence reading skill growth which are better measured by behavioral EF rating scales than by cognitive EF assessment tasks.

1.4.1 Rational for Use of Behavioral Rating Scales

Factors that may be better measured by behavioral rating scales of EF may be those that influence skill learning by reducing one's ability to adopt and utilize the strategies being taught in the educational/intervention setting. These include impairments in complex EF behaviors such as metacognition, task monitoring, and behavioral regulation skills. Goldberg (2005) laid out the necessity of intact executive functioning skills in order for learning to take place across all domains. Certain EF impairments, such as weak metacognition and error monitoring, therefore, may lead to increased difficulty learning new skills taught in a reading intervention.

1.4.2 Metacognitive Skills

Metacognitive skills may influence intervention responsiveness through altering the effectiveness with which an individual can learn skills being taught in the intervention. Metacognition refers to awareness of one's own cognition. In the domain of reading, this can refer to knowledge of reading, ability to apply strategies for successful reading, and ability to make predictions about how one will perform on a task. Therefore, it is not surprising that these skills influence one's ability to learn reading skills. Baker and Beall (2009) found that better readers display more metacognitive strategies, while Kohlic-Vehovec et al (2014) found that poorer metacognitive knowledge of text comprehension strategies was related to poorer reading comprehension scores. Furnes and Norman (2015) analyzed self-report measures of the three validated forms of metacognition in struggling and typically developing readers-metacognitive knowledge, metacognitive strategies, and metacognitive experiences, on self-predictions about how the individual would perform. Results from this study showed that struggling readers exhibited lower metacognitive knowledge about reading and made more inaccurate predictions about how they would perform on reading assessments. This was interpreted to reflect lack of insight into reading difficulties and reading skill in the struggling readers and suggests that multiple levels of metacognitive skills may influence ability to develop reading skills. It has also been found that metacognitive knowledge of reading and memory influences response to intervention (van Kraayenoord & Schneider, 1999) and that this relationship persists over time (Roeschl-Heils, Schneider, and van Kraayenoord, 2003). Intervention studies also support the role of metacognitive skills in effective response to skills training. Successful interventions for RD often require the use of metacognitive skills. It has been shown that intervention for reading difficulties have stronger outcomes when explicit skill training is paired with training in the use of metacognitive skills, so that these skills can be readily applied (Lovett et al 2012; Morris et al 2012). Therefore, those who struggle to apply and learn metacognitive skills may ultimately struggle to improve their reading skills through intervention.

1.4.3 Behavioral Regulation Skills

Behavioral regulation skills, consisting of the abilities to monitor oneself and one's emotional responses, may also influence intervention responsiveness through altering the effectiveness of the intervention. Torgesen et al (1999) and Vadasy et al (1997) found that in individual tutoring sessions, lack of behavioral regulation as measured through ratings of disruptive classroom behavior led many to respond weakly to reading skill interventions. A preliminary investigation by Hus (2014) found elevated impairment on both the BRI and MI in struggling readers. Kane

(2011) found that the BRIEF discriminated between children with and without reading disability. Hanbury (2008) found that both BRIEF index scores were higher, indicative of greater impairment, in those with poor reading comprehension skills. Locascio et al (2010) is one of few studies to have used both behavioral rating measures and cognitive measures of EF in a sample of children with reading impairments. The authors found that cognitive deficits in planning and organizing skills as measured through the Trails and Tower test of the DKEFS were associated with poorer reading comprehension skills. This study also measured behavioral measures of EF using the Behavioral Rating Inventory of Executive Function (BRIEF) and found significantly lower ratings of executive functioning skills in daily life (overall Executive Composite including both the BRI and MI) in those with word reading deficits (Locascio et al 2010).

Despite the fact that the literature has found distinctions between behaviorally measured and cognitively measured EF skills, both types of EF measurements have shown relationships to reading skills. Impairments in both behavioral regulation and metacognition may influence the efficiency with which an individual can participate and learn skills being targeted by an intervention. Behavioral impairments in EF domains may act as barriers to the skills being taught in an intervention teaching the individual, thereby decreasing the intervention's effectiveness.

1.4.4 Summary

In conclusion, both behaviorally and cognitively measured EF skills have been found to be significantly related to the development of successful reading and adequate performance of both basic and complex reading skills. Therefore, impairments in these EFs may influence a child's response to reading intervention.

1.5. Presence of EF Impairments in Disorders Comorbid with RD

1.5.1 RD and ADHD Comorbidity

Many of the above-mentioned executive functioning skills that are considered necessary for successful development/improvement of reading skills are also skills that are known to be impaired in attention deficit/hyperactivity disorder (ADHD). It is therefore not surprising that ADHD shares a high rate of comorbidity with RD (Willcutt & Pennington, 2000). Estimates of the co-occurrence of ADHD and RD range from 25 to 40 percent (Mayes, Calhoun, & Crowell, 2000; Semrud-Clikeman et al, 1992; Shaywitz, Fletcher, and Shaywitz, 1995), and shared genetic risk factors have been shown to exist between these two disorders (Gayan et al, 2005; Willcutt et al, 2007). Evidence also exists that ADHD and RD may result from dysfunction of similar core EF cognitive processes including, but not limited to, working memory impairment, inhibitory control, and sustained attention (Germano, Gagliano, and Curatolo, 2010; McGrath et al, 2011; Thaler et al., 2009; Van de Voorde et al. 2010). Furthermore, comorbid ADHD and RD is frequently associated with unique problems and worse outcomes when compared to those children diagnosed with only RD or only ADHD (Willcutt, 2000, 2001). Despite this high comorbidity, studies of intervention response in RD have typically used heterogeneous samples that do not systematically control for the occurrence of other comorbid conditions, such as ADHD. It is therefore frequently unknown whether a comorbid ADHD diagnosis significantly influences a child with RD’s response to reading intervention. However, if executive functioning impairments influence response to reading intervention, it is likely that poor readers with comorbid ADHD, a disorder frequently associated with significant executive functioning impairments, will show comparatively weaker intervention responsiveness than poor readers without ADHD.

1.5.2 ADHD and RD Shared Deficits-Working Memory

There is evidence to suggest that ADHD not only shares executive functioning deficits with RD, but also that these EF deficits are more severe in those with RD+ADHD than in those with either disorder alone. In the domain of working memory, a meta-analysis of 13 studies found significant impairments in verbal working memory on various cognitive tasks, including the WAIS-R Digit Span, in those with ADHD as compared to typically developing controls (Boonstra et al, 2005). Several meta-analyses (Alderson et al, 2013; Boonstra et al, 2010; Kasper et al, 2012; Martinussen et al, 2005; Willcutt et al, 2005) have also concluded that working memory impairments are a core cognitive deficit in ADHD, and they have led to working memory impairment consistently being noted as a core deficit of the disorder (Stevens, 2010). Recently, Friedman et al (2017) have shown that working memory skills are a mediator of applied problem-solving abilities in children with ADHD, further illustrating the extent to which such impairments may affect many types of academic performance in children with ADHD. Furthermore, working memory deficits have been shown to be more severe in those meeting criteria for both ADHD and RD than in those meeting criteria for either disorder alone. For instance, Kibby & Cohen (2008) showed significant weaknesses in verbal working memory in those with RD, significant weaknesses in visual-spatial working memory in those with ADHD, and both types of working memory impairment in those diagnosed with both disorders. Given the necessity of working memory skills for successful decoding and comprehension, it is logical that those with comorbid ADHD/RD could respond more poorly to intervention than those with RD alone.

Willcutt et al (2001; 2007) conducted a twin study of those with RD, ADHD, comorbid RD/ADHD, and neither disorder. They found that the comorbid group showed the greatest impairment on phonemic awareness measures as well as on executive function measures including those of working memory, inhibition, and set shifting. This result was interpreted to indicate that ADHD and RD share common etiologies of neuropsychological deficits such as working memory, and that these deficits are most severe in the comorbid group. Therefore, if working memory impairments in RD influence response to reading skill intervention, it is likely that those with ADHD as well as RD will show an even weaker intervention responsiveness due in part to their greater working memory deficit.

1.5.3 *ADHD and RD Shared Deficits-Inhibition and Interference Control*

Deficits in inhibition and interference control are also common to ADHD as well as RD. Barkley (1997) proposed that individuals with ADHD display a core deficit in behavioral inhibition. Barkley's theory suggested that the inability to inhibit current behaviors means that other executive functioning processes (i.e. working memory, error monitoring, focused attention) are not able to operate successfully. Pennington and Ozonoff (1996) conducted a large-scale review of studies of individuals with ADHD and found that inhibition was a core EF deficit in this population. Since this proposal two decades ago, several studies have found results supporting inhibition difficulties in ADHD. Geurts, Verte, Oosterlaan, Roeyers, & Sergeant (2004) compared a group of children diagnosed with ADHD to a group of typically developing children and found that performance on tasks of inhibition was significantly reduced in those with ADHD. A 2005 meta-analysis by Boonstra et al found significant difficulties in inhibition across thirteen studies of children with ADHD, and a 2010 study (Boonstra et al, 2010) concluded that inhibition difficulties are a primary and persistent EF deficit in adults with ADHD. Schoemaker et al (2012) found robust inhibition deficits in preschool children with ADHD as compared to those diagnosed with disruptive behavior disorder and those with no diagnosis.

Like the working memory impairment, impairments in inhibitory control have been found to be more severe in those with comorbid ADHD+RD than in those with either disorder alone. Willcutt et al (2001; 2007) found that a comorbid ADHD+RD group showed the greatest impairment on measures of inhibition, indicating that inhibitory control may be a neuropsychological deficit that is most severe in comorbid ADHD+RD. Van de Voorde et al (2010) found that while both children with RD and ADHD made significantly more inhibition errors on a Go/No-Go task than controls, those with comorbid ADHD and RD made more errors than either of the individual clinical groups. Stern and Shalev (2012) found that measures of inhibition, switching, and fluency on the DKEFS occurred equally across those with ADHD and with RD, although this study did not include a comorbid ADHD/RD group. Poon and Ho (2014) measured inhibitory control through several cognitive tasks, including the Stroop task and the contingency naming task, and found poorer interference and ability to ignore irrelevant stimuli in those with RD/ADHD than in those with either disorder alone. Most recently, Horowitz-Kraus et al (2016) measured ERPs and error-monitoring skills in individuals with only ADHD and in those with both ADHD+RD and found decreased error-monitoring activation as well as poorer performance on an error-monitoring task in the comorbid group. It is clear that impairments in inhibitory control may be a shared deficit between ADHD and RD, with greater impairment in those who have both disorders. If impairments in inhibitory control in subjects with RD influence their response to reading interventions, it is likely that those with RD as well as ADHD will show even weaker intervention responsiveness due in part to their greater inhibitory control deficits.

1.5.4 Behavioral Measurements of EF in Comorbid ADHD and RD

Behaviorally measured EF deficits have also been found in those with only ADHD or only RD, and more severe behavioral impairment has been found in those with ADHD+RD than those with either disorder alone. Miranda et al (2013) found elevated deficits on the metacognition and working memory subscales of the BRIEF in those with both ADHD and RD, with more severe deficits occurring in those with RD+ADHD than in those with either disorder alone. Locascio et al (2010) measured behavioral measures of EF using the Behavioral Rating Inventory of Executive Function (BRIEF) and found significantly lower ratings of executive functioning skills in daily life (overall Executive Composite) in those with word reading deficits (Locascio et al 2010). Poor behavioral regulation, which may well influence the effectiveness of reading interventions, is also commonly found in those with ADHD and may influence their ability to learn new skills. Liu et al (2017) found that youths diagnosed with ADHD displayed worse academic performance and higher rates of disruptive classroom behaviors that interfered with learning, even when they did not show any other comorbid behavioral disorders.

Those with ADHD have also been shown to struggle with behaviorally measured metacognitive skills including self-regulation, self-monitoring, and task monitoring. Studies using the MI of the BRIEF have shown weaker metacognitive skills in those with ADHD than in typically developing children (Miranda et al, 2015; Schroeder and Kelley, 2008). There have also been studies of cognitive tasks requiring metacognitive skills in those with ADHD, particularly in the domain of metacognitive experiences and self-evaluation/self-awareness. Children with

ADHD have been shown to make inaccurate predictions around their competence in a particular skill (Owens & Hoza, 2003), and have also been shown to inaccurately evaluate their performance after completing a cognitive task (Hoza et al, 2001; 2002). Similar inaccurate metacognitive results have been found in adults with ADHD (Knouse, Bagwell, & Murphy, 2005). To date, metacognitive skills have not been directly compared between groups of children with RD and children with comorbid RD and ADHD. However, given the necessity of metacognitive skills for successful reading skill development, and the pronounced impairments in such skills found in those with ADHD, it is likely that those with comorbid RD and ADHD may find interventions for reading skills less effective than those with RD alone

Given the importance of executive function skills in the development of successful reading skills, it is probable that struggling readers with poorer EF skills may show weaker response to reading interventions. It follows then that poor readers with comorbid conditions frequently associated with poor EF skills, such as ADHD, may also show weaker response to reading intervention then either condition alone. The presence of comorbid RD and ADHD may jointly determine how well they respond to intervention.

1.5.5 Rationale for Potential Relationship Between ADHD and Intervention Response

Weaker executive functioning skills associated with ADHD may impact response to reading intervention in two distinct ways. In one way, given the necessity of certain EF skills (i.e. working memory, inhibitory control) for the development of reading skills, those with more severe cognitive EF deficits may in turn have more severe reading impairments. Therefore, these individuals will show reading impairments that are more difficult to remediate through intervention. Separately, EF deficits may reduce the ability of individuals to participate fully in an intervention setting and learn the skills being taught. For example, those with these deficits may have difficulty ignoring extraneous stimuli during a classroom intervention session due to weak inhibitory control, or they may have difficulty self-monitoring throughout the intervention for portions of the lesson that they are struggling with. If those with EF deficits associated with ADHD show reduced responsiveness to reading skill intervention, it is likely that this effect occurs because those with significant EF deficits display more severe reading impairment as well as greater intervention interfering behaviors.

However, there are other deficits associated with ADHD aside from EF difficulties, such as inattention, hyperactive behavior, and impulsivity. Individuals with ADHD may also show reduced responsiveness to reading intervention due to these other, non-EF deficits. Therefore, when considering how comorbid ADHD affects response to reading skill intervention, it is important to determine the extent to which reduced intervention responsiveness is attributable to EF deficits, and the extent to which other non-EF deficits associated with ADHD, such as inattentiveness and hyperactive behavior, influence intervention responsiveness.

ADHD's non-EF attributes are characterized by difficulties focusing and sustaining attention and avoiding distraction (inattentive symptoms), hyperactive motor behavior that is poorly regulated and impulsive (hyperactivity/impulsivity), or a combination of both (DSM-V, 2013). These symptoms may also interfere with an individual's ability to fully attend to a classroom task and have long been known to have negative effects on academic performance (i.e. Biederman et al, 2004; Wu & Gau, 2013). Poor selective and sustained attention skills, which are known to be a core deficit in ADHD, have also been suggested to characterize lack of responsiveness to intervention in poor readers (O'Shaughnessy & Swanson, 2000; Snider, 1997; Vadasy et al, 1997). Wasserstein and Denckla (2009) also suggested that the addition of attention deficits in children with RD might be a key factor that leads to certain manifestations of reading disability being resistant to remediation. Langberg et al (2013) found that parent rated measures of inattention and hyperactivity on the DBRS were predictive of classroom performance in a group of middle school children with ADHD. Welsh et al (2010) found that attentional control was predictive of emerging literacy skills in early childhood, while Mclelland et al. (2007) found that behavior regulation was associated with emerging academic skills in preschoolers. Torgesen et al (1999) and Vadasy et al (1997) found that even in individual tutoring sessions, lack of behavioral regulation, as measured through ratings of disruptive classroom behavior, led many to respond weakly to reading skill interventions. In a few studies, poor ratings of classroom attention have also found to be associated with lack of responsiveness to reading intervention specifically (Snider et al, 1997; O'Shaughnessey and Swanson, 2000). Most recently, Liu et al (2017) found that youths diagnosed with ADHD displayed worse academic performance and higher rates of disruptive classroom behaviors that interfered with learning, even when they did not show any other comorbid behavioral disorders. Given the association of ADHD symptoms such as inattention and hyperactivity with weaker classroom performance, it is possible that such symptoms may also affect performance in a classroom intervention for RD independent of EF deficits. It is important to understand whether these symptoms predict variance in intervention responsiveness in the ADHD population above and beyond that which may be predicted by EF deficits.

From this perspective, examining EF deficits and intervention response in a group of individuals with RD+ADHD compared to a group of individuals with RD alone allows us to better understand the extent to which EF deficits predict response to reading skill intervention. If EF deficits explain much of the variance in intervention responsiveness, those with ADHD who show pronounced EF impairments should show reduced intervention responsiveness that can be attributed mainly to these EF impairments, with little additional variance explained by other non-EF ADHD symptoms (i.e., hyperactivity, inattention). Furthermore, those with ADHD who show only normal or mild EF impairments should not show reduced intervention responsiveness.

1.6. Aims of the Current Study

The primary goal of this study was to understand the extent to which EF impairments influence response to reading intervention. In addition, we were interested in whether behavioral or cognitive measurements of EF are differential and/or significant predictors of response to intervention in RD. In those with RD, we investigated whether behavioral and/or cognitive measurements of EF predicted intervention responsiveness above and beyond previously studied predictors, such as language and language-related skills. In those with co-morbid RD + ADHD, we investigated whether or not EF impairments predicted intervention responsiveness above and beyond phonological skills and other non-EF ADHD symptoms, such as inattention and hyperactivity.

Specific Aim 1: Investigate whether EF skills in a population of children with RD predict reliable change in reading skills post-intervention above critical phonological skills.

Hypothesis 1: Cognitive and behavioral measurements of EF will each contribute independent, separate but significant variances, in predicting reading skill change above that predicted by phonological skills.

Specific Aim 2: Compare baseline EF skills and change in reading skills post-intervention in groups with RD and ADHD+RD

Hypothesis 1: Behavioral and cognitive measurements of EF skills will show greater impairment in those with ADHD+RD when compared to only RD.

Hypothesis 2: Those with ADHD+RD will show less change in reading during intervention than those with RD only.

2 METHODS

2.1 Overview and General Design

The sample for this study consists of children in grades 3 and 4 selected for RD, but not excluding ADHD, so the sample includes those with RD only and RD+ADHD. All were enrolled in an empirically validated intervention for reading disabilities. For cognitive measurements of EF, we assessed inhibitory control using the DKEFS Trails Test and Color-Word Interference Test and working memory using a counting span task. For behavioral measurements of EF, we used the MI and BRI indices on parent and teacher reports from the BRIEF. We also collected measures of language-based skills that have been previously found to be associated with intervention responsiveness, such as phonological awareness (PA), naming speed, vocabulary, and sentence imitation.

Reliable change indices (RCI) for reading was derived from standardized reading measures focused on decoding and text-reading taken both at pre- and post-intervention. Change indices were entered into regression analyses with baseline cognitive and behavioral measurements of executive functioning in order to determine whether weaker EF skills were predictive of change in reading skills throughout the intervention. We conducted a hierarchical regression to determine whether EF impairments (behavioral and/or cognitive) predicted response to intervention above and beyond core phonological skills. Next, we assessed group differences in predicted reading skill change between those with RD only and those with ADHD+RD.

2.2 Procedures

2.2.1 Participant Screening and Recruitment

(1) Participants. Participants were part of a larger study on reading intervention response (Morris et al, in progress). Children who were identified as reading impaired by their schools were invited for pre-study screening. The initial sample consisted of children recruited from multiple schools in Atlanta, GA. From the grades 3 and 4 screening, 123 students from the Atlanta region were identified as eligible to participate in the study. A total of 110 participants completed the intervention and their reading was tested at four time points during the intervention. Measures of executive functioning and ADHD symptoms, completed by their parents and teachers, were missing/incomplete for some participants. Therefore, sample sizes varied for the different analyses to be reported based on the availability of specific measures. The sample sizes for the different analyses ranged from 99 to 110

(2) Inclusion/Exclusion Criteria. The reading impaired children had to be in grades 3 or 4 at the time of intervention. These children had to meet criteria for developmental dyslexia, scoring ≥ 1 SD below age-norm expectations (SS ≤85) on the subtests of the WJ-3 Broad Reading Cluster (Woodcock et. al, 2001), the Basic Reading Cluster, or TOWRE-2. All of these children were found to have standard scores below 85 (15^{th} %ile) on one or more of the WJ subtests (Letter-

Word ID, Word Attack, Reading Fluency, or Passage Comprehension, or the TOWRE-2 subtests.

(2) Exclusion Criteria. Reading impaired children selected to participate and receive the intervention also had a minimum level of low average intellectual functioning (SS >=80) on at least one subscale of the Wechsler Abbreviated Scale of Intelligence (WASI) (Wechsler, 2011). Parents completed questionnaires about their child's educational history, medical history, and language status as well as demographics. Children who were found to have > 15 absences per year from school, hearing impairments (>25 dB at 500_+ Hz bilaterally), uncorrected visual impairments (>20/40), serious emotional or psychiatric difficulties, and/or have had significant medical/neurological conditions were excluded from the study sample.

(3) Identification of Participants with ADHD+RD. For the purposes of Specific Aim 2, participants were separated into two groups-those who meet criteria for comorbid ADHD as well as RD, and those who meet criteria for RD only. Participants were considered to meet criteria for ADHD if either a parent or a teacher reported six or more ADHD symptoms on the Disruptive Behavior Disorders Rating Scale (see below). This method of identifying ADHD from the DBRS has been shown to be the strongest predictor of functional and academic impairment (Shemassian & Lee, 2016).

Table 1 Participant Characteristics

N (# of participants)	110
Sex	49 female, 61 male
Race (% White)	24 Caucasian, 2 Latinx, 4 Multiracial, 2 Asian, 78 African American
Age at examination (SD)	9.26 (0.70)
WASI 2-Scale IQ	93.8 (10.79)
Diagnostic groups	69 RD, 41 RD+ADHD

2.3 Materials and Methods

Descriptive statistics for all variables are displayed in Table 3, with distributions of these variables in Figures 2a-2e.

2.3.1 Assessments of Reading.

The following measurements of reading skills were assessed at Time 0 (baseline) and Time 70 (post-treatment, following 70 hours of intervention).

(1) Woodcock-Johnson Test of Achievement – 3 (WJ-3). Subtests of the Woodcock-Johnson III Tests of Achievement (WJ-III; Woodcock et al. 2001) were used to index reading skill: Letter-Word Identification; Word Attack; Reading Fluency; Passage Comprehension. Each of these subscales have has been shown to have high reliability/validity and normed on school age population. The Letter-Word Identification subtest is used to test an examinee's ability to decode real words and is untimed. The Word Attack subtest is a measure of phonological ability and requires the examinee to decode pseudowords. This subtest is untimed. The Reading Fluency subtest requires the examinee to read as many simple sentences as possible and correctly answer yes/no questions about them within a 3-minute time limit. The Passage Comprehension subtest measures the examinee's ability to understand written material and is untimed. This subtest requires the examinee to read sentences that are missing one key word and they must supply the missing word that completes the sentence. Two reading cluster scores are calculated from the WJ Scores: The WJ Basic Cluster (Letter Word Identification and Word Attack subtests) and the WJ Broad Cluster (Letter Word Identification, Reading Fluency, and Passage Comprehension subtests).

(2) Test of Word Reading Efficiency-TOWRE. The Test of Word Reading Efficiency – Second Edition (TOWRE-2; Torgesen, Wagner, and Rashotte, 2011) was used to test speeded reading proficiency of real words (Sight Word Efficiency) and pseudowords (Phonemic Decoding Efficiency). On both subtests the examinee reads as many items as possible in 45 seconds.

(3) Challenge Words Test. The *Challenge Words Test (Challenge Words Test;* Lovett et al, 1994; 2000) consists of 30 multisyllabic words not explicitly taught during the intervention and was used to measure metacognitive transfer of decoding strategies taught throughout the intervention.

(4) Test of Transfer. The *Test of Transfer (Test of Transfer;* Morris et al, 2012; Lovett et al, 2000) consists of 30 words that vary from keyword spelling patterns and are not explicitly tested during the intervention and are explicitly excluded. These words may vary in terms of their initial letters/phonemes and their sub-syllabic segments. This measure has been shown to produce 70-hour treatment effect sizes ranging from .65 to .85 (Morris et al, 2012; Lovett et al, 2000).

(5) Standardized Reading Inventory. The *Standardized Reading Inventory (SRI-2;* Newcomer, 1999) consists of stories read both silently and aloud. Comprehension is measured using questions about the text, whereas time to read each passage is measured as an indicator of reading rate.

2.3.2 Assessments of ADHD Symptoms.

ADHD symptoms were assessed through administration of two different questionnaires completed by parents and teachers for each child in the study at baseline before treatment began (Time 0).

(1) Disruptive Behavior Disorders Subscale. Each child's parent and teacher completed the Disruptive Behaviors Disorders Rating Scale (DBRS; Barkley, 1997). The DBRS consists of 26 items describing behaviors consistent with ADHD symptoms and asks parents/teachers to indicate whether the behavior occurs for their child "Never" "Sometimes" "Often" or "Very Often". The DBRS results in an overall score for different dimensions of externalizing symptoms, including ADHD symptoms, hyperactive-impulsive symptoms, and oppositional defiant disorder symptoms. The DBRS is a widely-used diagnostic tool with excellent psychometric properties, which includes scales used to identify, inattention and hyperactivity as well as oppositional and defiant behavior in children ages 5 – 13.

(2) Auditory Attention and Response Set subtest from NEPSY-II Attention and Executive Functioning Scale. As a cognitive measurement of attentional impairments common to ADHD, each participant was administered the Auditory Attention and Response Set subtest of the

NEPSY-II. The Auditory Attention & Response Set (normed for ages 5-16) was used to test selective auditory attention and the ability to shift and maintain new and complex sets at baseline testing (Time 0). For the Auditory Attention portion, the child hears an auditory recording instructing them to touch a red circle every time they hear ‘RED’ on the recording, yielding a maximum of 30 possible points (30 REDs). The Response Set portion asks the child to touch either a RED, BLUE or YELLOW circle when they hear one of those colors on the recording. Each test yields separate total scores and a contrast score to compare performance across these two tasks. Commission, omission, inhibitory errors and behavioral observations are also recorded to provide process scores for this attention measure.

2.3.3 Assessments of Executive Functioning-Behavioral

Behavioral measurements of executive functioning were also collected from parents and teachers of each child in the study at baseline before intervention (Time 0).

(1) Behavior Rating Inventory of Executive Functioning-BRIEF. The Behavior Rating Inventory of Executive Functioning (BRIEF; Gioia, Isquith, Guy, and Kenworthy, 2000) is a paper pencil questionnaire, measuring executive functioning in children and adolescents ages 5-18. Parent and teacher forms consist of 86 items each, giving measures in two indices: Behavioral Regulation (which is made up of three scales) and Metacognition (made up of five scales). Scores from these two indices yield an overall Global Executive Functioning score measuring overall executive functioning of a given child. The scales that comprise the Behavioral Regulation Index, *Inhibit, Shift,* and *Emotional Control,* focus on a child’s ability to control impulses, move freely from one activity to another, and regulate emotional responses appropriately. The scales that comprise the Metacognition Index, *Initiate, Working Memory,* *Plan/Organize, Organization of Materials and Monitor,* focus on a child's ability to independently generate ideas, hold and encode information, set goals, keep things in order, and assess their own performance.

2.3.4 Assessments of Executive Functioning-Cognitive

Cognitive assessments of executive functioning were collected from each child in the study at baseline before the intervention began (Time 0).

(1) Delis-Kaplan Executive Function Scale-DKEFS. The Delis-Kaplan Executive Function Scale (D-KEFS) is a well-validated and nationally normed measure of executive functioning in children (Delis, Kaplan and Kramer, 2001). The D-KEFS assesses elements of executive function within both verbal and spatial realms using a cognitive-process approach to analyze specific elements of higher order functions. Three key subtests were chosen from the D-KEFS, enabling testers to gain a broad understanding of various elements of a participant's executive function abilities.

The first subtest, the **Trail-making Test (TMT)**, measures flexibility of thinking and speed of processing on a sequencing task. The TMT is made up of five small tasks (Visual Scan, Number Sequencing, Letter Sequencing, Number-Letter Switching, and Motor Speed), each assessing a person's ability to sequence quickly, and finally, in Number-Letter Switching, assessing an ability to sequence while maintaining cognitive flexibility to switching sets.

The **Color-Word Interference Test** uses the 'Stroop Effect' to test cognitive flexibility, and inhibition by not only asking an individual to inhibit a response (in the Color-Word interference task), but also by instructing an individual to switch between inhibitory and non-inhibitory responses.

Finally, the **Sorting Test** measures concept-formation and problem-solving skills. The Sorting Test tests an individual's ability to freely sort 6 cards semantically, and categorically, as well as identify sorts that are displayed.

All three subtests utilize the D-KEFS Cognitive-Process Approach by allowing for assessment of individual components of each subtest (i.e. Numbers and Letter Sequencing) revealing strengths and weaknesses within a single domain of executive functioning. Each of these subtests has shown moderate convergent validity (Heaton et al, 1993) and moderate discriminant validity (Delis et al, 1987). Furthermore, the DKEFs subtests have been found to be sensitive to executive functioning deficits in numerous clinical populations (Delis, Kaplan, and Kramer, 2006).

(2) Digit Span Task. The Digit Span Task is a subtest of the WISC-IV (*WISC-IV*, Integrated Wechsler, 2004) used as a measurement of working memory capacity. This test requires participants to repeat a series of numbers in both forward and backwards orders, with the length of the series becoming increasingly longer and more difficult as the test continues.

2.3.5 Assessments of Phonological Processes and Language-Related Skills

(1) Comprehensive Test of Phonological Processing-CTOPP-2. The *Comprehensive Tests of Phonological Processing (CTOPP-2*; Wagner et al. 1999), was used as a measure of phonological awareness. Three CTOPP-2 subtests, *Elision, Blending,* and *Phoneme Isolation* form a composite score that measures a child's awareness of an access to the phonological structure of oral language. The Elision subtest measures the ability to remove individual phonemes from words to form other words (e.g. "say bed without saying "/b/", correct response: "ed"). The test becomes progressively more difficult until the deleted phonemes can no longer be detected through orthographic knowledge of a word. The Blending Words subtest is a measure of a child's ability to blend sounds to form words (e.g. "What word do these sounds make: j-ump?", correct response: "jump"). Finally, the Phoneme Isolation subtest measures the ability to isolate sounds within words (for example: "What is the second sound in the word *apple*?"). Items become more difficult as spelling strategy cannot be used.

2.3 Intervention.

Reading-impaired children underwent a multi-component intervention that has been developed and evaluated in federally funded research conducted by our collaborators at the Hospital for Sick Children in Toronto as well as by researchers in our group at Georgia State University. This intervention has shown robust positive effects on standardized measures of word reading, non-word decoding, and comprehension (Lovett et al., 2000; Lovett et al. 2012; Lovett et al. 2005; Lovett, Morris, et al. 2008; Morris et. al, 2012). Children were split into groups of 5-8 students for the intervention. The intervention groups were created based on level of functional reading vocabulary as estimated by the WJ-3 Letter-Word Identification subtest, and scores for each group were approximately within 1- 2 standard errors. This intervention was administered for a total of 70 hours, typically in 1-hour time blocks 4-5 days a week. Teachers administering the intervention had been trained by experienced and senior researchers, teachers, and by the developers. The onsite senior research teacher also monitored classroom implementation of the intervention and provided feedback to ensure that the intervention was delivered according to expectations. The intervention focuses on teaching strategies for decoding and word identification, text comprehension, vocabulary instruction, fluency and word reading efficiency, and motivational components to address low motivation for reading.

2.4 Data Analysis

2.4.1 Defining Variables

Response to Intervention Indices. Response to intervention was defined by the average reliable change indices (RCI, Jacobson and Truax, 1991; Christensen & Mendoza, 1986) using the reading skill assessments listed above. The RCI method has been shown to be effective in evaluating response to reading skill interventions (Frijters et al., 2013). The RCI is calculated by dividing the absolute change (the difference between post-intervention performance (Time 70) and pre-intervention (Time 0) performance) by the standard error of the pre-post difference. This results in a z score RCI for each measure. The average of the RCIs for the four decoding measures was used as the decoding outcome variable, and the average of the RCIs for the two text-reading measures was used as the text-reading outcome variable. The RCI decoding measure consisted of the WJ Word Attack, WJ Word Identification, the Test of Transfer, and the Challenge Words Test. The RCI text-reading/comprehension measure consisted of the WJ Passage Comprehension and SRI-2. For a diagram of this method, see Fig. 1.

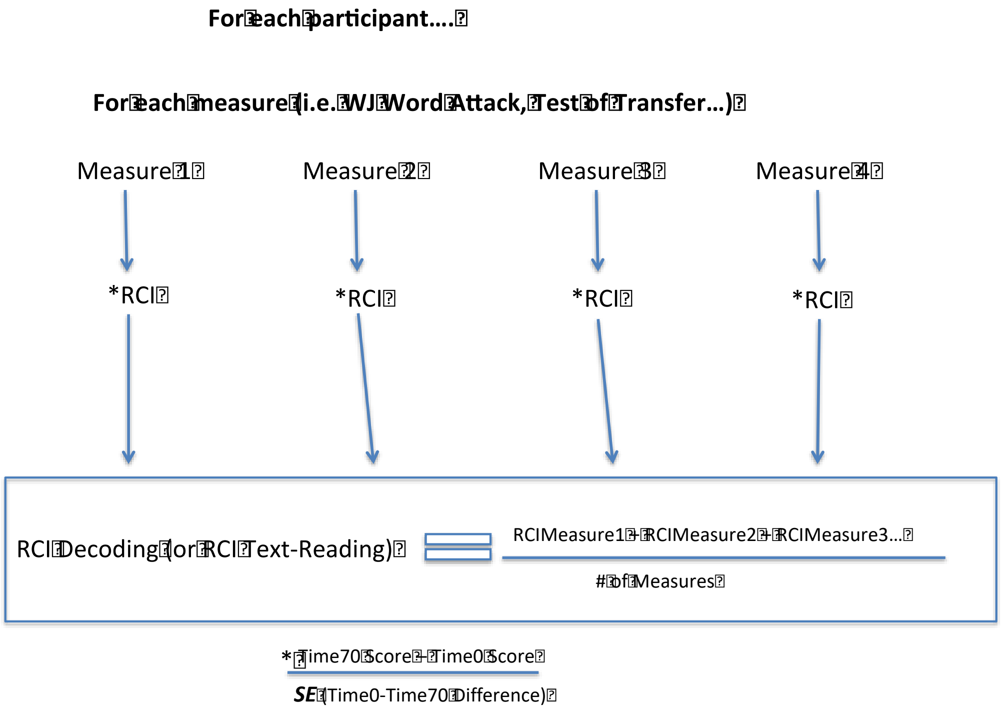

Figure 1 Description of Calculations for Outcome Variables

Table 1 Constructs of Interest and Neuropsychological/Behavioral Measurements

Construct of Interest	Measure	Behavioral Measure
Phonological Awareness	CTOPP_PA Standard Score	X
Working Memory	Digit Span Combined Scaled Score	BRIEF Working Memory (Part of Metacognition Index)
Inhibitory Control	DKEFS Color-Word Interference, Trial 4	BRIEF Inhibit (Part of Behavioral Regulation Index)
Cognitive Flexibility	DKEFS Trails, Trial 4 Number Letter Sequencing	BRIEF Shift (Part of Behavioral Regulation Index)
Problem Solving Skills	DKEFS Sorting, Free Sorting, Correct Sorts	BRIEF Initiate, Plan/Organize (Part of Metacognition Index)
Attention Regulation (Sustained Attention):	NEPSY-II Auditory Attention Total Correct Scaled Score	X
Attention Regulation (Divided Attention):	NEPSY-II Response Set Total Correct Scaled Score	X
Inattentiveness	X	DBRS Inattention
Hyperactivity/Impulsivity	X	DBRS Hyperactivity
Metacognition	X	BRIEF Metacognition Index
Behavioral Regulation	X	BRIEF Behavioral Regulation Index

Table 2 Descriptive Statistics of Predictor Variables

Variable Name	***N***	***M***	***SD***	***Skewness***	***SE Skewness***	***Kurtosis***	***SE Kurtosis***	***KS Test for Normality (p-value)***
DKEFS_TMT	107	6.90	3.73	.13	.23	-1.13	.46	<.01
DKEFS_CWI	107	8.50	3.61	-.44	.23	-.38	.46	<.001
DKEFS_SO	107	7.28	2.74	-.09	.23	-.76	.46	<.01
BRIEF BRI	109	52.40	12.93	.69	.23	-.10	.46	<.01
BRIEF MI	109	55.20	12.90	-.59	.23	1.96	.46	.200
DBRS Inattention	101	9.22	5.97	.54	.24	-.33	.48	.02
DBRS Hyperactivity	101	7.05	5.54	.72	.24	-.31	.48	<.01
NEPSY-II Auditory Attention	110	8.60	3.56	-.41	.23	-.71	.46	<.001
NEPSY-II Response Set	110	8.60	3.69	-.34	.23	-.56	.46	<.001
Digit Span (B)	100	8.38	2.17	.24	.24	.16	.48	<.001
CTOPP-2 PA Composite	110	79.41	10.84	.65	.23	.92	.45	.01

N *= sample size for variable,* ***M*** *= mean of variable,* ***SD*** *= standard deviation of variable,* ***SE*** *= standard error,* ***KS Test*** *= Kolmogorov-Smirnov Test of Normality,* ***DKEFS_TMT =*** *DKEFS Trail Making Test,* ***DKEFS_CWI =****DKEFS Color Word Interference Test,* ***DKEFS_SO*** *= DKEFS Sorting Test,* ***BRIEF BRI*** *= BRIEF Behavioral Regulation Index,* ***BRIEF MI*** *= BRIEF Metacognition Index,* **DBRS Inattention** *= Disruptive Behavior Rating Scale Inattention Score (parent rated),* **DBRS Hyperactivity** *= Disruptive Behavior Rating Scale Hyperactivity Score (parent rated),* **CTOPP-2 PA Composite** *= Comprehensive Test of Phonological Processing Phonological Awareness Composite*

Table 3 Descriptive Statistics of Outcome Variable

Variable Name	***N***	***M***	***SD***	***Skewness***	***SE Skewness***	***Kurtosis***	***SE Kurtosis***	***KS Test for Normality (p-value)***
Z Score Reliable Change Indices Across Decoding Measures	110	-0.10	.61	-.43	.23	1.05	.45	.20
Z Score Reliable Change Indices Across Text Reading Measures	110	.28	.61	.56	.23	.64	.45	.20

N *= sample size for variable,* ***M*** *= mean of variable,* ***SD*** *= standard deviation of variable,* ***SE*** *= standard error,* ***KS Test*** *= Kolmogorov-Smirnov Test of Normality*

2.4.2 Non-normality of Variables

The distributions of cognitive and behavioral measurements of EF, as well as the distributions for measures of phonological awareness and ADHD symptoms, showed various types of non-normality. To avoid violating the assumption of normality in our analyses, Spearmann's correlations and bootstrapped confidence intervals were used. Measures of skewness, kurtosis, and normality tests are shown in Table 3, and histograms for each variable are shown in Appendix 1.

2.4.3 Analyses for Specific Aim 1

The first hypothesis of Aim 1 is that behavioral measurements of EF skills (scores on the BRIEF) will contribute independent variance in predicting change in reading skills post-intervention above the variance contributed by phonological skills. The second hypothesis of Aim 1 is that cognitive measurements of EF skills (scores on the DKEFS subscales and Digit Span Backwards) will contribute independent variance in predicting change in reading skills over the course of intervention above that contributed by phonological skills. We tested both hypotheses using hierarchical regression models. In the first stage of each model, composite standard scores from the CTOPP-2 Phonological Awareness Composite (CTOPP-2 PA) were entered as predictors using the decoding reliable change indices and text reading reliable change indices as independent outcome variables. Second stage models were created using the T scores for the Behavioral Regulation Index (BRIEF BRI) and Metacognition Index (BRIEF MI) from the BRIEF to assess Hypothesis 1, and DKEFS Trails, (DKEFS_TMT), Color-Word Interference (DKEFS_CWI), Sorting (DKEFS_SO), and Digit Span Backwards (DSB) to assess Hypothesis 2, with each model including the CTOPP-2 PA as well. If either of these hypotheses are supported, then R^2 values would be significantly higher for stage 2 models when compared to results from stage 1. Such results would indicate that behavioral and/or cognitive measurements of EF predict change in decoding and/or text reading skills over the course of intervention above that which was predicted by baseline phonological awareness skills. We examined the partial correlations for each predictor to clarify the separate contributions of each of the behavioral and cognitive measurements.

To ensure that we can validly interpret the variances contributed by the predictors as independent, we verified that the predictors did not show high collinearity through calculation of

Variance Inflation Factors (VIF). The distribution of scores on the BRIEF is known to be positively skewed (Gioia et al., 2000), which could violate the regression assumption of normally distributed residuals. While this should not influence the regression coefficients, it could lead to overestimation of the standard errors for the coefficients, leading to inaccurate significance tests. In addition, evaluation of the distributions of DKEFS scores appear to be skewed. Therefore, we used bootstrapped confidence intervals for the significance tests, to correct for violations of the normality assumption.

The third hypothesis of Aim 1 predicts that behavioral and cognitive measurements of executive functioning will each contribute independent variances in predicting reliable change indices in decoding and text reading, above the variance contributed by phonological awareness measures. To test this hypothesis, we evaluated entering the cognitive measurements in stage 2 and the BRIEF predictors as stage 3 in the models or reversed the entry order by including the BRIEF predictors in stage 2 and the cognitive measurements in stage 3, depending on which of these measures was found to be the strongest predictor of change in decoding/text-reading over the course of intervention. If our hypothesis is supported, we expect that addition of the BRIEF index scores subsequent to the DKEFS scores (or vice versa) would lead to significantly more variance being explained in the reliable change indices for reading outcomes.

2.4.4 Analyses for Specific Aim 2

The first hypothesis of Aim 2 is that those with diagnoses of both ADHD and RD will show greater EF impairments than those children with only RD diagnoses. We hypothesize that T scores on the BRIEF will be higher, indicating greater rated impairments in those with ADHD+RD when compared to those with only RD, whereas scaled scores on subtests of the

DKEFS will be lower, indicating more severe EF cognitive deficits. We conducted two separate MANOVAs with ADHD status as the grouping variable. Preliminary analyses showed only weak correlations between the DKEFS subscale scores and BRIEF indices in our data, consistent with our hypothesis that the variances contributed by behavioral and cognitive EF data are somewhat independent (see Appendix 2, Table 5.) Therefore, we conducted one MANOVA using the two BRIEF index scores as outcome variables and another MANOVA using the three DKEFS subtests as outcome variables. If our hypothesis was supported, then BRIEF MI and BRI scores should be significantly higher for the group with ADHD+RD compared to the group with RD, and DKEFs subtest scaled scores should be lower for the group with ADHD+RD compared to the group with RD alone.

The second hypothesis of Aim 2 is that higher levels of ADHD symptoms will be associated with smaller reliable change indices in decoding and text-reading skills over the course of intervention and will contribute significant variance above that contributed by phonological awareness skills. Each ADHD dimension measurement (DBRS Inattention and DBRS Hyperactivity) was entered as a predictor into an independent linear regression model with reliable change indices for decoding/text-reading skills each used as outcome variables. In the first stage of each model, CTOPP-2 PA scores were entered as the initial predictor of the reliable change indices for decoding/text-reading skills as outcome variables. Following this, second stage models were created which included the Inattention scale of the DBRS (DBRS Inattention), the Hyperactivity scale of the DBRS (DBRIS Hyperactivity), and the NEPSY-II Auditory Attention and Response Set scaled scores (NEPSY-II AA, NEPSY-II RS). If our hypothesis was supported, then R^2 values would be significantly higher for stage 2 of these models when compared to stage 1, indicating that ADHD symptoms significantly predicted variance in reliable change indices in decoding/text-reading skills above that which is predicted by baseline phonological awareness skills. The distribution of scores on the DBRS is known to be positively skewed (Barkley & Murphy, 1998), which may violate the regression assumption of normally distributed residuals. As this could lead to overestimation of the standard errors for the coefficients, we used bootstrapped confidence intervals for any value indicating significance. If our hypothesis was supported, higher DBRS scores will be predictive of reliable change indices in decoding and text-reading skills over the course of intervention.

3 RESULTS

3.1 Results for Specific Aim 1

For Aim 1, a total of 99 participants had complete data and were included in all analyses. We created two hierarchical regression models, with step 1 of each model including the pre-intervention CTOPP-2 phonological awareness composite score (CTOPP-2 PA) as predictor of the reliable change indices in decoding (RCI: Decoding) or text-reading (RCI: Text-Reading) as outcome variables. Step 2 of each model included the pre-intervention CTOPP-2 phonological awareness composite score and each of the pre-intervention measures of executive functioning.

3.1.1 Predicting Reliable Change Index (RCI) for Decoding from EF Functioning

For the model with RCI: Decoding as the outcome, variance inflation factors indicated very low levels of multicollinearity (*VIF* = 1.26 for PA, 1.56 for BRI, 1.59 for MI, 1.27 for DKEFS_TMT, 1.23 for DKEFS_CWI, 1.15 for DKEFS_SO, and 1.07 for DSB). None of the pre-intervention predictors in either model step explained a significant amount of variance in the decoding RCIs. Statistics for each predictor in the model with RCI: Decoding as the outcome is shown in table 6.

Table 4 Hierarchical Regression, Reliable Change Index: Decoding

Aim 1 Model	***B***	***SE B***	***β***	***p***	***Partial Correlation (r)***
Step 1					
Constant	-0.65	0.51		.20	
CTOPP-2 PA	0.01	0.01	0.10	.31	.10
Step 2					
Constant	-0.67	0.72		.35	
CTOPP-2 PA	0.01	0.72	0.14	.23	.13
DKEFS_CWI	0.03	0.02	0.18	.11	.17
DKEFS_SO	-0.01	0.03	-0.02	.83	-.02
DKEFS_TMT	-0.02	0.02	-0.14	.22	-.13
DSB	-0.03	0.03	-0.10	.34	-.10
BRIEF BRI	>0.01	0.01	-0.04	.76	-.03
BRIEF MI	>0.01	0.01	0.06	.66	.05

Step 1 R^2= 0.01, Step 2 R^2 = .08, R^2 change = 0.01, p > 0.1, N = 99

***B** = unstandardized beta coefficient, **SE B** =standard error of unstandardized beta coefficient, **β =** standardized beta coefficient, **p =** p-value, **CTOPP-2 PA Composite** = Comprehensive Test of Phonological Processing Phonological Awareness Composite, **DKEFS_CWI =**DKEFS Color Word Interference Test, **DKEFS_SO** = DKEFS Sorting Test, **DKEFS_TMT =** DKEFS Trail Making Test, **BRIEF BRI** = BRIEF Behavioral Regulation Index, **BRIEF MI** = BRIEF Metacognition Index*

3.1.2 Predicting Reliable Change Index for Text-Reading from EF Impairment

For the model with RCI:Text-Reading as the outcome, variance inflation factors also indicated very low levels of multicollinearity (*VIF* = 1.29 for CTOPP-2 PA, 1.57 for BRIEF BRI, 1.59 for BRIEF MI, 1.29 for DKEFS_TMT, 1.23 for DKEFS_CWI, 1.20 for DKEFS_SO, and 1.07 for DSB). None of the pre-intervention predictors explained a significant amount of variance in RCI:Text. Statistics for each predictor in the model with RCI:Text-Reading as the outcome are shown in Table 6.

Table 5 Hierarchical Regression, Reliable Change Index: Text Reading

Aim 1 Model	***B***	***SE B***	***β***	***P***	***Partial Correlation (r)***
Step 1					
Constant	-0.24	0.52		.64	
CTOPP-2 PA	0.01	0.01	0.12	.29	.12
Step 2					
Constant	-0.40	0.72		.58	
CTOPP-2 PA	0.01	0.01	0.14	.23	.13
DKEFS_CWI	0.03	0.02	0.15	.18	.14
DKEFS_SO	0.01	0.03	0.05	.65	.05
DKEFS_TMT	-0.01	0.02	-0.04	.74	-.04
DSB	-0.04	0.03	-0.15	.15	-.15
BRIEF BRI	0.01	0.01	0.19	.14	-.15
BRIEF MI	-0.01	0.01	-0.14	.28	-.11

Step 1 R^2= 0.01, Step 2 R^2 = .05, R^2 change = 0.04, $p > 0.1$, N = 99

B*= unstandardized beta coefficient,* ***SE B*** *=standard error of unstandardized beta coefficient,* ***β =*** *standardized beta coefficient,* ***p =*** *p-value,* ***CTOPP-2 PA Composite*** *= Comprehensive Test of*

Phonological Processing Phonological Awareness Composite scaled score, ***DKEFS_CWI =****DKEFS Color Word Interference Test scaled score,* ***DKEFS_SO*** *= DKEFS Sorting Test scaled score,* ***DKEFS_TMT =*** *DKEFS Trail Making Test scaled score,* ***BRIEF BRI*** *= BRIEF Behavioral Regulation Index T score,* ***BRIEF MI*** *= BRIEF Metacognition Index T score*

Neither pre-intervention behavioral measurements of EF (BRIEF indices) nor cognitive measurements of EF (DKEFS) were found to be significant predictors of reliable change index in decoding or text-reading, contrary to our hypotheses for Aim 1. Surprisingly, the pre-intervention CTOPP-2 Phonological Awareness Composite score was also a non-significant predictor of change in either the decoding or text-reading RCIs. The addition of the EF measures in model 2 did not improve model fit nor explain significant additional variance beyond CTOPP-2 PA. Partial correlations between EF measurements and RCI: Decoding/Text-Reading were also non-significant, indicating that these pre-intervention predictors explained very little variance in indices of response to intervention even when the effect of PA was controlled.

3.2 Results for Specific Aim 2

3.2.1 Executive Functioning Deficits in Participants with RD only Compared to those with ADHD+RD

In order to investigate Aim 2 hypothesis 1, whether parent-reported pre-intervention executive functioning impairments were higher in participants diagnosed with ADHD+RD vs. those with RD only, we conducted a multivariate analysis of variance (MANOVA) comparing the BRIEF index scores of the two aforementioned groups. A total of 109 participants' data was available for these analyses (ADHD+RD = 41, RD only = 68). Mean scores for each group on the experimental measures are outlined in Table 8.

Table 6 Mean Scores for Each Group (ADHD+RD and RD Only) On Experimental Measures

	RD (*N* = 69)			ADHD+RD (*N* = 41)	
	M	*SD*		*M*	*SD*
RCI: Decoding	-0.14	0.07		-0.05	0.10
RCI: Text Reading	0.27	0.07		0.31	0.10
CTOPP-2 PA Composite	79.65	1.31		79.00	1.70
DKEFS_TMT	7.03	0.48		6.70	0.53
DKEFS_CWI	8.45	0.45		8.58	0.56
DKEFS_SO	7.31	0.33		7.23	0.44
DSB	8.55	0.29		8.11	0.31
BRIEF BRI	49.13	1.55		57.98	1.75
BRIEF MI	50.26	1.53		63.59	1.30
NEPSY-II AA	8.81	3.99		8.22	2.69
NEPSY-II RS	8.67	3.67		8.49	3.76

__M__ = mean, __SD__ = standard deviation, __RCI:Decodin__g =Reliable change index for decoding measures, __RCI: Text-Reading__ = Reliable change index for text-reading measures, CTOPP-__2 PA Composite__ = Comprehensive Test of Phonological Processing Phonological Awareness composite scaled score, __DKEFS_CWI =__DKEFS Color Word Interference Test scaled score, __DKEFS_SO__ = DKEFS Sorting Test scaled score, __DKEFS_TMT =__ DKEFS Trail Making Test scaled score, __BRIEF BRI__ = BRIEF Behavioral Regulation Index T score, __BRIEF MI__ = BRIEF Metacognition Index T score, __NEPSY-II AA__ = NEPSY-II Auditory Attention Scaled Score, __NEPSY-II RS__ = NEPSY-II Response Set Scaled Score

Using Wilk's lambda, there was a significant effect of ADHD diagnosis on reported behavioral regulation (BRI) and metacognition (MI) deficits, Λ = .74, $F(2, 106) = 18.23$, $p < .001$. It is important to note that Box's test for the MANOVA was significant, Box's M = 9.79, $p = .02$. This indicates that the covariance matrices of the outcome variables cannot be assumed to be equal across the ADHD+RD and RD only groups. Robustness of the MANOVA to violation of this assumption cannot be assumed given the fact that the group sizes are different. Therefore, these MANOVA results may be susceptible to Type 1 error and should be interpreted with caution.

In addition, univariate ANOVAs on both of the BRI and MI outcome variables independently also revealed significant differences between the groups, $F(1,107) = 13.33$, $p < .001$, $F(1, 107) = 36.13$, $p < .001$, respectively. For the univariate ANOVA with BRIEF MI as the outcome variable, Levene's test also indicated unequal variances ($F = 3.87$, $p = .05$). Therefore, we evaluated this comparison using the Kruskal-Wallis Test, which also indicated significant differences on the MI between the two groups, $H(1) = 32.98$, $p < .001$. A Kruskal-Wallis test was not performed using the BRIEF BRI, as Levene's test for the univariate ANOVA with BRIEF BRI did not indicate unequal variances ($F = .14$, $p = .71$).

We also conducted a multivariate analysis of variance (MANOVA) comparing scores on pre-intervention cognitive measurements of executive functioning (DKEFS subscale scores and Digit Span scores) between the two groups. A total of 100 participants' data was available for this analysis ($N = 100$, RD = 62, ADHD+RD = 38). Levene's test did not indicate unequal variances for DKEFS or Digit Span scores between groups (DKEFS_TMT: $F = 1.67$, $p = .20$, DKEFS_CWI: $F = .51$, $p = .48$, DKEFS_SO: $F =.29$, $p = .59$, DSB: $F = .55$, $p = .46$). Using Wilk's lambda, there was no significant effect of ADHD diagnosis on reported cognitive measures of executive functioning, $\Lambda = .99$, $F(4, 95) = .29$, $p = .89$

Overall, it appears that in this study population, behaviorally reported pre-intervention measurements of executive dysfunction are elevated in those with ADHD+RD as compared to those with RD alone. However, performance on pre-intervention cognitive measurements of executive functioning skills do not appear to be significantly poorer in those with ADHD+RD as compared to those with only RD.

3.2.2 Executive Functioning Deficits in Participants with ADHD+RD

To address Aim 2, hypothesis 2, decoding and text-reading treatment changes were compared between the two groups described above (RD and ADHD+RD), using the full available sample of participants (N = 110). A univariate analysis of variance (ANOVA) comparing both groups on RCI: Decoding was not significant, $F(1,110) = .54$, $p = .47$. An ANOVA comparing both groups on RCI: Text reading was also non-significant, $F(1,110) = .08$ $p = .79$. Contrary to our hypothesis, those with ADHD+RD diagnoses did not show lower reliable change indices in either the decoding/text-reading domains as compared to those RD children without ADHD diagnoses.

3.2.3 Predicting Reliable Change in Reading Measures from Diagnostic Category

We then conducted linear regressions to examine whether level of pre-intervention ADHD symptomatology was predictive of the reliable change index in decoding and text-reading outcomes, above variance contributed by CTOPP-2 PA scores. A total of 101 participants had DBRS scores available for analysis. Neither DBRS Inattention nor DBRS Hyperactivity scores were found to be significant predictors of RCI: Decoding or RCI: Text-reading. Results are shown in Tables 9-12.

Table 7 Hierarchical Regression, CTOPP-2 and DBRS Inattention Predictors of RCI: Decoding

Aim 2 Model	***B***	***SE B***	***β***	***P***	***Partial Correlation (r)***
Step 1					
Constant	-0.55	0.46		.24	
CTOPP-2 PA	0.01	0.01	0.10	.32	.10
Step 2					
Constant	-0.60	0.52		.25	
CTOPP-2 PA	0.01	0.01	0.12	.34	.10
DBRS Inattention	0.01	0.01	0.02	.83	0.02

Step 1 R^2= 0.01, Step 2 R^2= 0.10 R^2 change = -0.001, p =.83, N = 101

b *= unstandardized beta coefficient,* ***SE B*** *=standard error of unstandardized beta coefficient,* ***β =*** *standardized beta coefficient,* ***p =*** *p-value, ,* ***CTOPP-2 PA Composite*** *= Comprehensive Test of Phonological Processing Phonological Awareness Composite scaled score,* ***DBRS Inattention*** *= Disruptive Behavior Rating Scale (Parent Version) Inattention score*

Table 8 Hierarchical Regression, CTOPP-2 and DBRS Hyperactivity Predictors of RCI: Decoding

Aim 2 Model	***B***	***SE B***	***β***	***P***	***Partial Correlation (r)***
Step 1					
Constant	-0.55	0.46		.24	
CTOPP-2 PA	0.01	0.01	0.10	.33	.10
Step 2					
Constant	-0.54	0.50		.28	
CTOPP-2 PA	0.01	0.01	0.10	.34	.10
DBRS Hyperactivity	>0.01	0.01	>0.01	.98	>.01

Step 1 R^2= 0.01, Step 2 R^2= 0.01 R^2 change = -0.001, p =.98, N = 101

b *= unstandardized beta coefficient,* ***SE B*** *=standard error of unstandardized beta coefficient,* ***β =*** *standardized beta coefficient,* ***p =*** *p-value, ,* ***CTOPP-2 PA Composite*** *= Comprehensive Test of Phonological Processing Phonological Awareness Composite scaled score,* ***DBRS Hyperactivity*** *= Disruptive Behavior Rating Scale (Parent Version) Hyperactivity Score*

Table 9 Hierarchical Regression, CTOPP-2 and DBRS Inattention Predictors of RCI: Text Reading

Aim 2 Model	***B***	***SE B***	***β***	***P***	***Partial Correlation (r)***
Step 1					
Constant	0.23	0.46		.63	
CTOPP-2 PA	0.01	0.01	0.02	.88	0.02
Step 2					
Constant	0.15	0.52		.78	
CTOPP-2 PA	0.01	0.01	0.03	.81	0.02
DBRS Inattention	0.01	0.01	0.40	.73	0.04

Step 1 R^2= 0.02, Step 2 R^2= 0.001 R^2 change = -0.001, p =.73, N = 101

b *= unstandardized beta coefficient,* ***SE B*** *=standard error of unstandardized beta coefficient,* ***β =*** *standardized beta coefficient,* ***p =*** *p-value,* ***CTOPP-2 PA Composite*** *= Comprehensive Test of Phonological Processing Phonological Awareness Composite scaled score,* ***DBRS Inattention*** *= Disruptive Behavior Rating Scale (Parent Version) Inattention Score*

Table 10 Hierarchical Regression, CTOPP-2 and DBRS Hyperactivity Predictors of RCI: Text Reading

Aim 2 Model	***B***	***SE B***	***β***	***P***	***Partial Correlation (r)***
Step 1					
Constant	0.23	0.46		.63	
CTOPP-2 PA	0.01	0.01	0.02	.88	.02
Step 2					
Constant	-0.05	0.50		.92	
CTOPP-2 PA	0.01	0.01	0.05	.63	.05
DBRS Hyperactivity	0.02	0.01	0.15	.14	.15

Step 1 R^2= 0.02, Step 2 R^2= 0.001 R^2 change = -0.001, p =.73, N = 101

***b** = unstandardized beta coefficient, **SE B** =standard error of unstandardized beta coefficient,*

***β** = standardized beta coefficient, **p** = p-value, **CTOPP-2 PA Composite** = Comprehensive Test of Phonological Processing Phonological Awareness Composite scaled score, **DBRS Hyperactivity** = Disruptive Behavior Rating Scale (Parent Version) Hyperactivity Score*

We also conducted linear regressions to examine whether pre-intervention cognitive measurements of attention (NEPSY-II AA and NEPSY-II RS) were predictive of RCI: Decoding and RCI: Text-Reading. A total of 110 participants had NEPSY scores available for analysis. It is noteworthy that these cognitive measurements of attention showed weak, non-significant correlations with all of the DBRS subscales (see Appendix 1, Table 5). Neither NEPSY Auditory Attention scaled scores or NEPSY Response Set scaled scores were found to be significant predictors of RCIs for Decoding or Text Reading. Results of these analyses are outlines in Tables 13-16.

Table 11 Hierarchical Regression, CTOPP-2 and NEPSY-II Auditory Attention Predictors of RCI: Decoding

Aim 2 Model	***B***	***SE B***	***β***	***P***	***Partial Correlation (r)***
Step 1					
Constant	-0.76	0.44		.08	
CTOPP-2 PA	0.01	0.01	0.15	.13	.15
Step 2					
Constant	-0.76	0.44		.09	
CTOPP-2 PA	0.01	0.01	0.15	.13	.15
NEPSY-II AA	-0.01	0.02	0.02	.96	-0.02

Step 1 R^2= 0.02, Step 2 R^2= 0.02 R^2 change = -0.001, p =.96, N = 110

b *= unstandardized beta coefficient,* ***SE B*** *=standard error of unstandardized beta coefficient,* ***β =*** *standardized beta coefficient,* ***p =*** *p-value,* ***CTOPP-2 PA Composite*** *= Comprehensive Test of Phonological Processing Phonological Awareness Composite scaled score,* ***NEPSY_II AA =*** *NEPSY=II Auditory Attention scaled score*

Table 12 Hierarchical Regression, CTOPP-2 and NEPSY-II Auditory Attention Predictors of RCI: Text-Reading

Aim 2 Model	***B***	***SE B***	***β***	***P***	***Partial Correlation (r)***
Step 1					
Constant	0.05	0.43		.90	
CTOPP-2 PA	0.01	0.01	0.05	.59	.05
Step 2					
Constant	0.04	0.45		.90	
CTOPP-2 PA	0.01	0.01	0.05	.61	.05
NEPSY-II AA	0.01	0.02	0.02	.86	.02

Step 1 R^2 = 0.01, Step 2 R^2 = 0.02, Step 2 R^2 change = 0.01, p = .86

b *= unstandardized beta coefficient,* ***SE B*** *=standard error of unstandardized beta coefficient,* ***β =*** *standardized beta coefficient,* ***p =*** *p-value,* ***CTOPP-2 PA Composite*** *= Comprehensive Test of Phonological Processing Phonological Awareness Composite scaled score,* **NEPSY_II AA =** *NEPSY=II Auditory Attention scaled score*

Table 13 Hierarchical Regression, CTOPP-2 and NEPSY-II Response Set Predictors of RCI: Decoding

Aim 2 Model	***B***	***SE B***	***β***	***P***	***Partial Correlation (r)***
Step 1					
Constant	0.05	0.44		.90	
CTOPP-2 PA	0.01	0.01	0.05	.59	.05
Step 2					
Constant	0.02	0.44		.97	
CTOPP-2 PA	0.01	0.01	0.02	.02	.81
NEPSY-II_RS	0.02	0.02	0.14	.16	.14

Step 1 R^2 = 0.02, Step 2 R^2 = 0.03, Step 2 R^2 change = 0.01, p = .36

b *= unstandardized beta coefficient,* ***SE B*** *=standard error of unstandardized beta coefficient,* ***β =*** *standardized beta coefficient,* ***p =*** *p-value,* ***CTOPP-2 PA Composite*** *= Comprehensive Test of Phonological Processing Phonological Awareness Composite scaled score,* ***NEPSY_II RS =*** *NEPSY=II Response Set Scaled score*

Table 14 Hierarchical Regression, CTOPP-2 and NEPSY-II Response Set Predictors of RCI: Text-Reading

Aim 2 Model	***B***	***SE B***	***β***	***P***	***Partial Correlation (r)***
Step 1					
Constant	-0.76	0.43		.08	
CTOPP-2 PA	0.01	0.01	0.15	.13	.15
Step 2					
Constant	-0.72	0.44		.10	
CTOPP-2 PA	0.01	0.01	0.16	.10	.16
NEPSY-II_RS	-0.02	0.02	-0.09	.36	-.09

Step 1 R^2 = 0.01, Step 2 R^2 = 0.02, Step 2 R^2 change = 0.02, p = .16

b *= unstandardized beta coefficient,* ***SE B*** *=standard error of unstandardized beta coefficient,* ***β =*** *standardized beta coefficient,* ***p =*** *p-value,* ***CTOPP-2 PA Composite*** *= Comprehensive Test of Phonological Processing Phonological Awareness Composite scaled score,* ***NEPSY_II RS =*** *NEPSY=II Response Set Scaled score*

3.3 Post Hoc Categorical Analyses

We also explored post-hoc whether groups of individuals classified as having or not having cognitive and/or behavioral executive functioning impairments would show different levels of change across intervention.

3.3.1 Classification of Individuals with Cognitively Measured/Behaviorally Measured EF Impairments

Individuals were classified as having behavioral executive functioning impairments if they obtained T scores above 65 on at least one of the two BRIEF indices (BRI and MI). A total of 29 individuals were classified as having behavioral EF impairments, with 80 additional classified as not having behavioral EF impairment. Individuals were classified as having cognitive executive functioning impairments if they obtained scaled scores below 7 on at least 2 of the following measures: DKEFS Trail Making Test, DKEFS Color-Word Interference, DKEFS Sorting, Digit Span Backwards. A total of 51 individuals were classified as having cognitive EF impairments, with 49 remaining as not impaired. The number of individuals with either type of impairment is shown in Table 17.

Table 15 Percentages of Participants Classified as Having Behavioral/Cognitive EF Impairment

	Behaviorally Measured EF Impairment	Cognitively Measured EF Impairment	Both
Impaired	29 (~27%)	51(51%)	32 (~32%)
Total Data Available	109	100	99

3.3.2 Categorical Analyses of Cognitively Measured EF Impairments and RCIs

A one-way ANOVA between these two groups revealed no significant difference in RCI: Decoding between the groups, $F(1,98) = 0.42$, $p = .52$. In addition, no significant difference in RCI:Text Reading was observed between the groups, $F(1,98) = 0.35$, $p = .55$.

3.3.3 Categorical Analyses of Behaviorally Measured EF Impairments and RCIs

A one-way ANOVA between these two groups revealed no significant difference in RCI:Decoding between the groups, $F(1,107) = 0.33$, $p = .57$. In addition, no significant difference in RCI:Text reading was observed between the groups, $F(1,107) = 0.02$, $p = .90$.

3.4 Post-Hoc Analyses Using WJ Outcome Scores

None of our pre-intervention measures of executive functioning and/or ADHD symptoms emerged as significant predictors of change in reading skill following intervention. This result was unexpected, given the robust literature showing correlations between these study variables and changes in reading skills. It is possible that, although these pre-intervention measures are not predictive of changes in reading skill following intervention, they may be predictive of final reading levels following intervention, a result that would be consistent with the literature. We therefore examined the correlations between the same predictor variables and both Time 0 and Time 70 for the WJ Broad and WJ Basic Cluster scores. We also constructed regression models that included all pre-intervention predictors that showed significant correlations with Time 70 scores in order to investigate these relationships.

Table 16 Spearman Correlations between WJ Cluster Scores and Predictors

Variable Names	**Time 0 WJ Basic Score**	**Time 70 WJ Basic Score**	**Time 0 WJ Broad Score**	**Time 70 WJ Broad Score**
NEPSY-II Auditory Attention (*N* = 110)	.00	.01	.07	.01
NEPSY-II Response Set (*N* = 110)	.04	.00	.13	.08
DBRS Inattention (*N* = 101)	-.02	-.10	-.19*	-.14
DBRS Hyperactivity (*N* = 101)	-.03	-.07	-.11	-.06
CTOPP-2 Phonological Awareness (*N = 110*)	.32**	.33**	.21*	.29**
DKEFS Trail Making (*N* = 107)	.15	.07	.18^	.16^
DKEFS Color-Word Switching (*N* = 107)	-.02	.01	-.01	.03
DKEFS Sorting Test (*N* = 107)	.17	.13	.25**	.30**
Digit Span Backwards (*N* = 100)	.01	-.03	.01	-.05
BRIEF Metacognition Index (*N* = 109)	-.15	-.13	-.21*	-.21*
BRIEF Behavior Regulation Index (*N* = 109)	-.16	-.10	-.09	-.08

*** Correlation is significant at the 0.01 level (2-tailed).*

** Correlation is significant at the 0.05 level (2-tailed).*

Table 17 Spearman Correlations between WJ Cluster Scores

Variable Names	**Time 0 WJ Basic Score**	**Time 70 WJ Basic Score**	**Time 0 WJ Broad Score**	**Time 70 WJ Broad Score**
Time 0 WJ Broad Score	.81**	. 72**	---	.73**
Time 0 WJ Basic Score	---	.80**	.81**	.76**
Time 70 WJ Basic Score	.76**	---	.81**	.85**
Time 70 WJ Broad Score	.79**	.85**	.73**	---

*** Correlation is significant at the 0.01 level (2-tailed).*

** Correlation is significant at the 0.05 level (2-tailed).*

Unsurprisingly, Time 70 WJ Cluster scores (both Basic and Broad) showed the highest correlations with Time 0 WJ scores. Time 70 WJ Cluster scores (Basic and Broad) showed the second highest correlations with the pre-intervention CTOPP Phonological Awareness composite. This finding is consistent with the substantial literature on the role of phonological awareness in predicting reading abilities. Because Time 0 WJ scores and CTOPP scores showed the strongest correlations with Time 70, we constructed our hierarchical regression models with Time 0 WJ scores in step 1 and CTOPP PA scores in step 2. Step 3 for each model added the remaining predictors into the equation to predict their relationships with Time 70 WJ scores.

3.5.1 Predicting Time 70 WJ Basic Scores

Predictor variables that were significantly correlated with Time 70 WJ Basic cluster scores included Time 0 Basic Cluster score and CTOPP Phonological Awareness score. Sample size was 110 (N = 110) for the analysis.

Table 18 Hierarchical Regression Predicting WJ Time 70 Basic Scores

Model for Predicting Time 70 WJ Basic Score	***B***	***SE B***	***β***	***p***	***Partial Correlation (r)***	***R^2***
Constant	155.80	28.03		>.001		
Time 0 WJ Basic Score	0.68	0.06	0.72	>.01	.73	.48
CTOPP-2 PA	0.11	0.09	0.09	.20	.12	.006

Step 1 R^2 == 0.56, Step 2 R^2 = 0.57, Step 2 R^2 change = 0.01, p = .20

__b__ = unstandardized beta coefficient, __SE B__ =standard error of unstandardized beta coefficient, __β =__ standardized beta coefficient, __p =__ p-value, __Time 0 WJ Basic Score =__ standard score on WJ-3 Basic Reading Cluster at time 0, __CTOPP-2 PA Composite__ = Comprehensive Test of Phonological Processing Phonological Awareness Composite scaled score

3.5.2 Predicting Time 70 WJ Broad Scores

The only variables showing significant correlations with Time 70 WJ Broad Cluster Scores were Time 0 WJ Broad Cluster Scores, CTOPP-2 Phonological Awareness Composite, and DKEFS Sorting, and BRIEF Metacognition. The use of these variables in the regression led to a final sample size of 104 (N = 104). Results of the analysis are displayed in Table 20 (see below).

The addition of pre-intervention CTOPP PA scores explained additional variance in Time 70 WJ Broad Cluster scores above that contributed by the corresponding Time 0 Broad Cluster scores. DKEFS Sorting and BRIEF Metacognition indices, however, did not contribute additional variance above that explained by CTOPP and Time 0 Broad Cluster score. When the analysis was run with DKEFS Sorting entered before CTOPP, it still did not explain additional variance in Time 70 above that contributed by Time 0 Broad Cluster score.

Table 19 Hierarchical Regression Predicting Time 70 WJ Broad Scores from Time 0 Broad Scores, CTOPP PA, DKEFS Sorting, and BRIEF Metacognition Index

Model for Predicting Time 70 WJ Broad Score	***B***	***SE B***	***β***	***p***	***Partial Correlation (r)***	R^2
Constant	118.01	27.18		>.01		
Time 0 WJ Broad Score	0.76	0.06	0.78	>.01	.80	.53
CTOPP-2 PA	0.12	0.06	0.12	.04	.20	.01
DKEFS_SO	0.14	0.24	0.04	.55	.06	>.01
BRIEF MI	-0.03	.05	-0.03	.59	-.05	>.01

Step 1 R^2 ***= 0.56, Step 2*** R^2 ***= 0.57, Step 2*** R^2 ***change = 0.02, p = .12***

b *= unstandardized beta coefficient,* ***SE B*** *=standard error of unstandardized beta coefficient,* ***β =*** *standardized beta coefficient,* ***p =*** *p-value,* ***Time 0 WJ Basic Score =*** *standard score on WJ-3 Basic Reading Cluster at time 0,* ***CTOPP-2 PA Composite*** *= Comprehensive Test of Phonological Processing Phonological Awareness Composite scaled score,* ***DKEFS_SO*** *= DKEFS Sorting Test scaled score,* ***BRIEF MI =*** *BRIEF Metacognition Index T score*

3.5.3 Categorical Analyses of Cognitively Measured EF Impairments and WJ Baseline Reading and WJ Reading Outcomes

We explored post hoc whether the individuals classified as having or not having cognitively measured EF impairments showed significantly different baseline WJ reading skills, and whether WJ reading skills post-intervention differed between these groups. A one-way ANOVA revealed no significant difference in baseline WJ Basic Cluster scores between the two groups, $F(1, 98) = 1.84$, $p = .18$. However, there was a marginally significant difference in baseline WJ Broad Cluster scores between the two groups, $F(1, 98) = 2.93$, $p = .09$. In addition, no significant difference in post-intervention WJ Basic Cluster scores or post-intervention WJ Broad Cluster scores was found between the two groups, $F(1, 98) = 0.02$, $p = .90$, $F(1,98) = 1.41$, $p = .24$, respectively.

3.5.4 Categorical Analyses of Behaviorally Measured EF Impairments and WJ Baseline Reading and WJ Reading Outcomes

We explored post hoc whether the individuals classified as having or not having behaviorally measured EF impairments showed significantly different baseline WJ reading skills, and whether WJ reading skills post-intervention differed between these groups. A one-way ANOVA revealed no significant difference in baseline WJ Basic Cluster scores between the two groups, $F(1, 107) = 1.86$, $p = .18$. However, there was a significant difference in baseline WJ Broad Cluster scores between the two groups, $F(1, 107) = 4.37$, $p = .04$. In addition, no significant difference in post-intervention WJ Basic Cluster scores was found between the two groups, $F(1, 107) = 1.59$, $p = .21$. However, post-intervention WJ Broad Cluster scores was found to differ significantly between the two groups, $F(1,107) = 4.55$, $p = .04$. Overall, WJ broad cluster scores at baseline and post-intervention showed differences between those with and without behaviorally measured EF impairments, while WJ Basic Cluster scores did not show such differences.

4 DISCUSSION

Substantial literature shows relationships between executive functioning skills, ADHD symptoms, and concurrent reading skills. The current study supported these findings, but further evaluated whether EF skills and ADHD symptoms are also predictive of change in reading skills over the course of a reading intervention. Our initial analyses revealed no significant effect of baseline behavioral or cognitive executive functioning deficits when predicting reliable change indices of reading skills following intervention. In addition, measures of ADHD symptoms were also not predictive of change in reading skills following intervention.

Our hypothesis that baseline executive functioning skills and ADHD symptoms would predict change in reading skill following intervention represents a novel hypothesis. To our knowledge, no prior study has evaluated this question. Despite a null result for this novel hypothesis, our post-hoc analyses findings were consistent with the previous literature. Post-hoc analyses revealed that phonological awareness, ADHD inattentive symptoms, selective attention, metacognitive skills, mental flexibility and set switching abilities were significantly correlated with children's reading performances at both the pre-intervention and post-intervention time points. Behavioral measures of executive functioning were also found to be significantly more severe in those with diagnoses of ADHD+RD compared to those with RD only. Due to the fact that results predicting initial and outcome reading levels do corroborate the research literature, we believe that the null findings are unlikely to be the result of divergence of our sample, or measurement methodology, from that of previous studies. Rather, these null results may be due to the inability of these measurement domains to predict the amount of *change* in reading skills related to intervention.

4.1 Methodological Limitations to Measurement of Change

The key question arising from our results is why we found EF and ADHD symptoms to be predictive of both baseline and post-treatment reading abilities but not predictive of the degree of change in reading skills. There may be several methodological limitations related to our ability to measure change in reading, particularly related to the use of the reliable change indices as the metric of change. We found large variability in our reliable change indices for both text-reading and decoding measures. For the full sample (N = 110), RCIs ranged from -2.18 to 1.46 for decoding, and -0.97 to 2.49 for text-reading. As a point of reference, an RCI of 1.00 or greater represents a 1 standard error of the difference scores based on the test norms and is frequently used as a level of change considered to be psychometrically reliable. Our analyses differed slightly from typical RCI measurements in that we used the average of four RCIs across measures as the outcome variable. We found that out of 110 individuals, only 4 individuals showed average RCIs above 1.00 for the decoding measures, and only 13 showed average RCIs above 1.00 for text-reading measures. Therefore, it is possible that these averaged RCI values do not adequately capture individual's reliable change across specific domains of reading. Models in which measurements of change involve only two data points as the outcome variable, as in this case, are also known to lead to reduced estimations of the relationships between predictors and the outcomes as compared to methods of measuring change with more data points. This occurs due to variable reliability in the outcome measure. In the outcome measures created for this study, reliability may have been particularly reduced as we averaged across four outcomes with different standard errors. Overall, the nature of our outcome measurements may have attenuated the resulting estimates of the relationship between outcome and predictors.

4.1.2 Predicting change from change

Many studies in the literature have found cognitive and behaviorally measured executive functioning skills to be predictive of concurrent reading skills but have not studied whether these are predictive of changes in reading skills over time (i.e. Cain, Oakhill, and Bryant, 2004; DeMagistri, Richards, and Canet Juric, 2014; Kohlic -Vehovec et al ,2014; Locascio et al, 2010). Studies that have sought to predict change in reading skills (i.e. Kegel & Bus, 2013; Swanson et al, 2007) frequently use a measure of *change* in underlying cognitive EF skills (i.e. working memory, inhibition) between the two time points at which reading skills were measured. For example, Swanson et al (2007) found that *growth* in working memory skills differed significantly between skilled readers and those with RD. This study's results demonstrated the relevance of working memory to reading, but more specifically, the relevance of the growth/improvement in working memory to growth/improvement in reading skills. It may be the case that prediction of improvement in reading skill is best predicted by improvement and changes in executive functioning skills over the treatment period, rather than only by baseline executive functioning skills.

4.2 Relationship of EF Impairment and Reading Skills

4.2.1 Variance Explained by EF

Another possibility is that executive functioning skills are related (share variance) with general reading abilities but are not critically important for the growth of reading skills following such a short period of intervention. Even in the significant post-hoc analyses, only a small proportion of the variance in Time 0 and Time 70 reading scores was explained by any of the EF or ADHD scores. Importantly, none of these scores predicted significant variance in Time 70 scores above that contributed by Time 0 scores. This result supports past literature suggesting that measurements of baseline cognitive characteristics do not predict significant variance in post-intervention reading outcomes when controlling for baseline reading skills. A meta-analysis by Stuebing et al (2015) found that baseline cognitive characteristics known to be related to reading predicted on average ~2% of the variance in outcomes when pre-test skills were accounted for. Notably, Stuebing et al (2014) found that working memory predicted less than 0.1% of the variance when pre-test was accounted for, similar to our results. It is possible that executive functioning skills are important for the development of reading skills, but not sufficient. If other factors such as initial reading skill level are of greater importance than executive functioning in predicting outcome following intervention, than executive functioning skills may predict very small proportions of variance in reading outcomes when considered independently of these factors. When these factors are considered, effects of the executive functioning measures may be reduced to non-significance. Many past studies did not include a pre-test/baseline level of the outcome reading measure of interest in their analyses. Percentages of variance in reading outcomes explained by executive functioning measures in these prior studies (i.e. Cain, Oakhill, and Bryant, 2004; Engel de Abreu et al, 2014; DeMagistri et al, 2014; Miranda et al; 2015) ranged from 4.5% to 12.5%. When pre-test was not accounted for, several of the cognitive predictors evaluated in this study predicted variances in reading outcomes similar to the variances reported in the literature (i.e. ~2.5% for DKEFS TMT, 9% for DKEFS-Sorting, 4.4 % for BRIEF MI).

4.2.2 Mechanisms for EF Influence on Reading Skills

Earlier, we described two potential, non-mutually exclusive mechanisms for how EF impairments could influence response to intervention**.** One possibility is that impaired readers with more severe executive functioning impairments also have more substantially impaired baseline reading skills, leading them to require more intensive remediation in order for improvement. This first hypothesis was partially supported by our finding that those with cognitively measured EF impairments showed marginally weaker baseline scores on the WJ Broad Cluster, and by our finding that those with behaviorally measured EF impairments showed significantly weaker baseline scores and post-intervention scores on the WJ Broad cluster. Therefore, although not predictive of the amount of growth over the course of intervention, we did find that those with cognitively measured EF impairments also showed poorer reading skills.

Another possibility is that behavioral manifestations of executive functioning impairments, including problems with metacognition and self-regulation, etc., may interfere with one's ability to learn and benefit from reading skill instruction. Although the presence of behaviorally measured EF impairments did not impact change in reading over the course of intervention, this second possibility is partially supported by our finding of stronger differences in baseline reading skills between those with behaviorally measured (BRIEF) as opposed to cognitively measured EF impairments. Notably, the group classified as having behaviorally measured EF impairments showed weaker baseline and post-intervention performance specifically on the WJ Broad Cluster, and not the WJ Basic Cluster**.** Unlike the Basic Cluster, the WJ Broad Cluster includes the Reading Fluency and Passage Comprehension subtests. These subtests may place increased demand on behavioral regulation by requiring the child to avoid distraction and complete a task quickly (Reading Fluency), or to maintain focus during a complex task (Passage Comprehension). Therefore, it is logical that those with behavioral EF impairments may show weaker baseline reading skills, and weaker post-intervention reading skills explained by the lower baseline skills.

Overall, our findings substantiate the literature in showing that both behavioral and cognitively measured EF deficits are related to reading skill. The presence of these deficits may have interfered with the children's ability to learn to read when they were among large numbers of children in typical classroom settings, hence their reading disabilities. However, if these deficits did interfere with the acquisition of reading skills in the children's previous classrooms, why might it be the case that they do not predict improvement in reading skills throughout the study intervention?

4.2.3 Effects of the intervention setting

It is possible that these executive functioning deficits may be less relevant to growth in reading skills when reading skills are being taught in a specialized, small group intervention setting. Individuals receiving this type of intervention experience more specialized attention and fewer distractions than they would in a typical classroom setting. It is easy to see how executive functioning impairments such as difficulty inhibiting irrelevant information or keeping track of instructional steps could interfere with a child's ability to learn reading skills in a classroom. However, it is possible that in smaller groups of up to 8 individuals, such as in this study intervention, difficulties such as these can be more easily accommodated by the instructor (i.e. through repetition of instructions, re-direction of children who become distracted, etc.). This may reduce the effects of executive functioning difficulties on reading skill development.

Unlike the current study, the majority of the past research on executive functioning skills and growth in reading skills did not implement a controlled, small group intervention (i.e. DeAbreu et al, 2014; Kegel and Bus, 2013; Swanson et al, 2007). The impact of executive functioning skills in reading skill growth may be different depending on whether reading instruction is administered to a large group of children in a typical classroom vs. a small group of children such as the intervention setting in this study. Further research may wish to compare the relevance of executive functioning skills to reading skill growth in small group intervention settings vs. in typical classroom settings.

4.3 Differences from past literature on phonological awareness

Given the robust literature on the role of phonological awareness in the development of reading skills and response to intervention (see Al Otaiba & Fuchs, 2006; Stuebing et al, 2014), it is surprising that we did not find phonological awareness skills to be a significant predictor of growth in reading skills. Differences from past literature with regard to the use of a single time point of measurement rather than using a measurement of change in phonological awareness may have influenced these results. Past studies frequently used phonological awareness measures to predict reading outcomes rather than predicting measures of change over the course of intervention (i.e. Hatcher & Hulme, 1999). Other studies have compared *growth* in phonological awareness, rather than pre-intervention phonological skills, to growth in reading skills (i.e. Vellutino et al, 1996).

It is clear from the literature that phonological awareness skills are necessary for the development of reading skills. The literature supports a substantial relationship between phonological awareness and reading scores at the end of interventions, a relationship that is supported by our results. However, our results indicated that baseline phonological awareness represented a significant yet small proportion of the variance in predicting reading following intervention (not change during intervention), roughly 12% in both the WJ Basic and WJ Broad Reading clusters. In addition, there was no significant contribution of phonological awareness to post-intervention reading outcomes beyond the variance explained by baseline reading skills.

It is possible that phonological awareness skills may be only a single cognitive ability among many other equally important abilities that are necessary for efficient reading skill development. Fletcher et al (2011) evaluated different cognitive characteristics among those subjects who did and did not respond well to reading interventions. They found that while phonological awareness differed between groups of individuals who did or did not respond well to intervention, it did not predict the variance in responder status beyond what was predicted by baseline reading levels. This result is consistent with our findings. In summary, phonological awareness skills may represent one of many necessary components of the variance in reading skill but may not account for much predictive variance in how much change may take place in reading following intervention once initial reading levels are accounted for.

In summary, when it comes to predictions of response to reading intervention, the whole may be greater than the sum of its parts. If successful reading involves a complicated interplay of several different cognitive and behavioral variables, such as in the model proposed by Vellutino et al (2004), growth in reading may be best predicted by a measure that encapsulates the complicated interplay among key multiple changing attributes as best as is possible. Baseline measures of reading skills, which represent a more holistic measure of the variation in any one of the many key components needed for successful reading, may be the best method index to use for predicting reading skill growth.

4.4 Influence of ADHD Symptoms

We initially hypothesized that poorer response to intervention would occur among those with ADHD+RD compared to those children with just RD, due to the expected increased executive functioning impairments found in this subgroup. While we did find increases in behavioral measures of executive functioning deficits in those with ADHD+RD compared to just RD, these deficits were not significantly predictive of response to reading intervention. Consistent with past research, we also found strong negative correlations between phonological awareness skills and reports of ADHD symptoms. Small negative correlations between baseline ADHD inattention symptoms and initial as well as post-intervention reading skills were also found. Similar to our findings regarding EF impairments, ADHD Inattention symptoms appear to be associated with poorer baseline and post-intervention reading skills. Consistent with the literature, inattentive symptoms were more predictive of reading impairment than hyperactive/impulsive symptoms. These inattentive symptoms were also more predictive of the WJ Broad as opposed to the WJ Basic Cluster, consistent with research indicating that ADHD symptoms have strong influence on reading comprehension skills (Passage Comprehension of WJ Broad) in particular. The Reading Fluency subtest in this cluster might also be particularly affected by difficulty maintaining attention and avoiding distraction, as it is a timed measure.

It is possible that children demonstrating ADHD symptoms in this sample showed reduced levels of baseline reading skills as a result of the ADHD symptoms having interfered with reading skill acquisition in previous classroom settings. However, ADHD symptoms may not have been predictive of response to reading skill intervention in this study due to the smaller group setting in which reading skill instruction took place. This intervention setting may have decreased the negative impact of ADHD symptoms on children's learning as it may lessen demands on sustained attention and self-regulation skills.

It is also notable that we obtained only a baseline measurement of ADHD symptoms. As we hypothesized with regard to executive functioning measures, it is possible that change in ADHD symptoms (i.e. measured at different time points) would show a relationship with the level of change in reading skill, even if a baseline level of ADHD symptoms were not predictive of change in reading skill. It would be interesting to investigate whether remediation of ADHD symptoms may affect degree of remediation of reading, or vice versa.

4.5 Limitations

There are several limitations to our present study and conclusions. First, we did not make use of a wait list control condition when implementing our intervention, so we cannot say what the results would look like in a group of children with RD who received typical classroom instruction vs. classroom instruction plus an explicit, small group intervention. Second, our assignment of participants to the ADHD vs. ADHD+RD group was based on questionnaire results based on parent/teacher ratings. We did not have access to clinical diagnoses of ADHD by trained professionals following comprehensive assessment and evaluation measures. Therefore, it is possible that certain individuals were assigned to the ADHD group who would not be considered to have ADHD following more comprehensive assessments, adding error variance to our predictions. Finally, a possible major limitation of this research is the lack of repeated measure of executive functioning measurements so that change in such could be identified and possibly used for prediction purposes. While baseline measurements of executive functioning were not predictive of change across reading skill intervention, it is possible that measurements of change in these variables could be more associated with change in reading following intervention. Further studies may wish to evaluate this question.

4.6 Summary

We investigated whether behaviorally or cognitively measured executive functioning deficits or ADHD symptoms influenced change over the course of intervention. Contrary to our hypothesis, we did not find relationships between these variables and change in reading skills over the course of intervention. Although EF deficits and ADHD symptoms were not found to be predictive of reading skill change, we did find that both behavioral and cognitive EF impairments, as well as ADHD symptoms, were correlated with baseline and post-intervention reading skills, consistent with past literature. However, despite being predictive of post-intervention reading skills, none of the EF measurements or measures of ADHD symptoms predict additional variance in reading skills above that predicted by baseline reading skills.

Successful reading requires a complex interaction of various different skills. Variance in reading outcomes predicted by baseline measures of EF was found to be small, indicating that individual EF skills may represent only small fractions of the necessary components needed for successful reading. Therefore, measurement of these skills may not be an efficient means of identifying individuals who are likely to respond well to reading skill intervention, especially when more comprehensive assessments of baseline reading skills are available.

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APPENDICES

Distributions of Scores

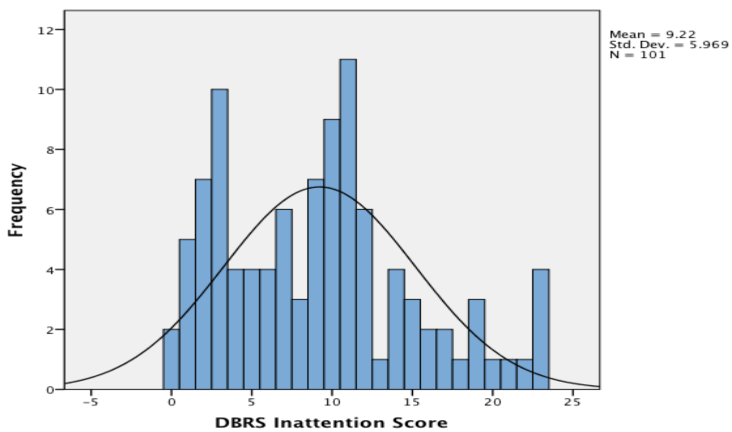

Figure 2a. Distribution of DBRS Inattention Score

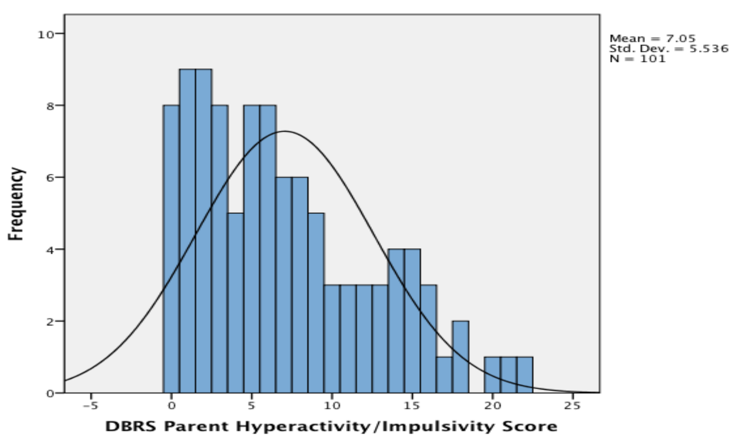

Figure 2b. Distribution of DBRS Hyperactivity Scores

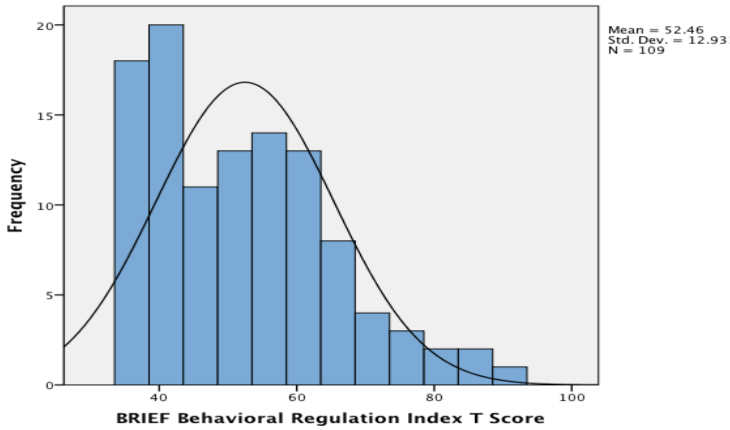

Figure 2c. Distribution of BRIEF BRI T Scores

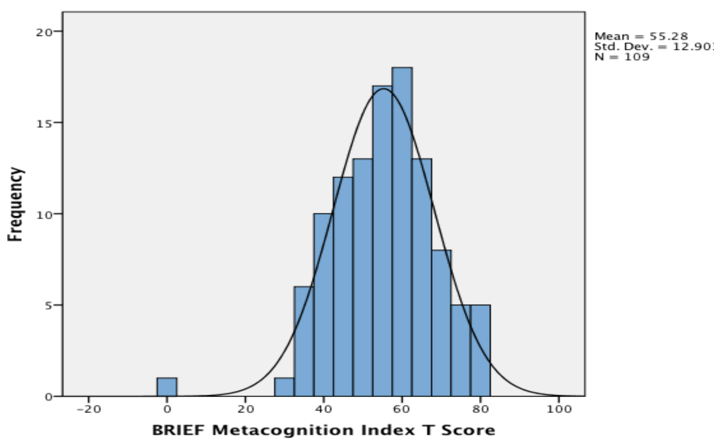

Figure 2d. Distribution of BRIEF MI T

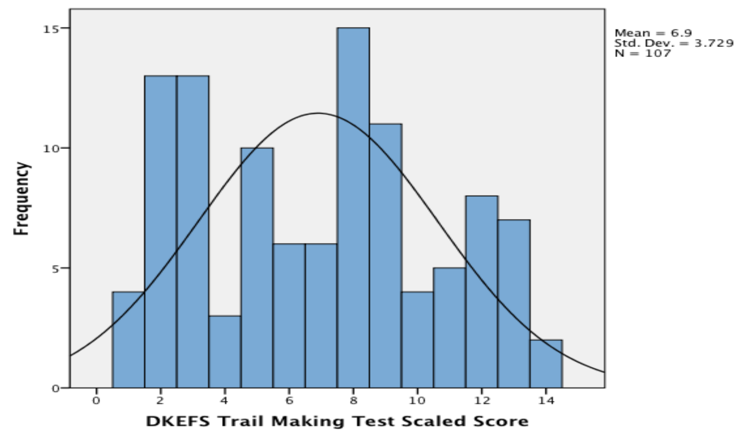

Figure 2e. Distribution of DKEFS

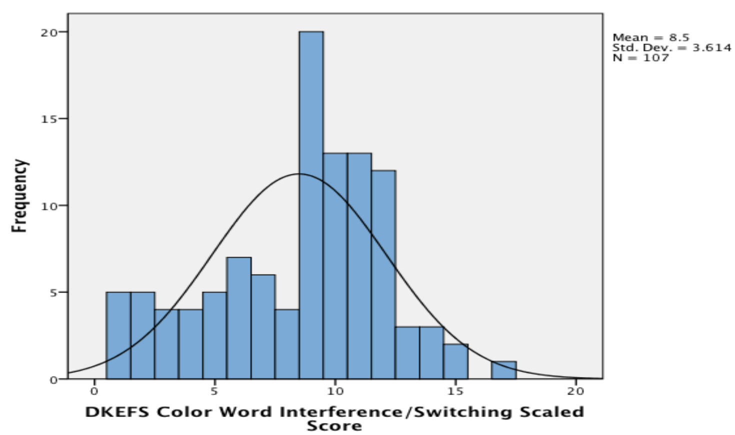

Figure 2f. Distribution of DKEFS Color-Word Interference Scaled Scores

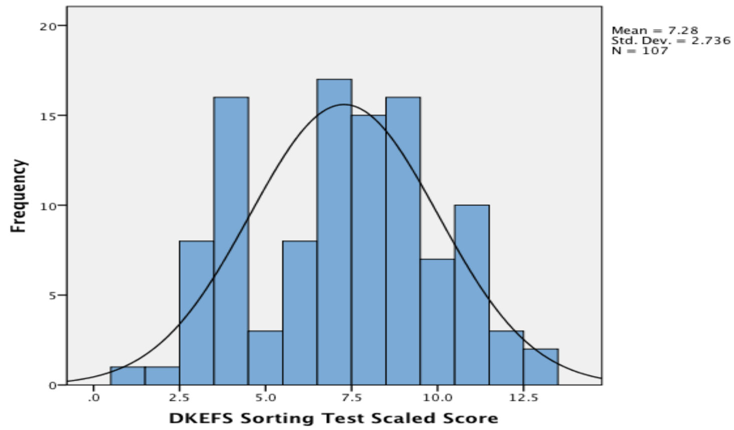

Figure 2g. *Distribution of DKEFS Sorting Test Scaled Scores*

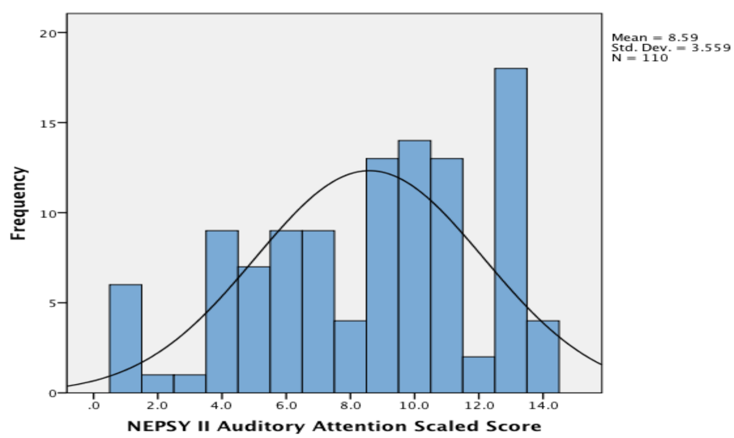

Figure 2h. *Distribution of NEPSY-II Auditory Attention Scaled Scores*

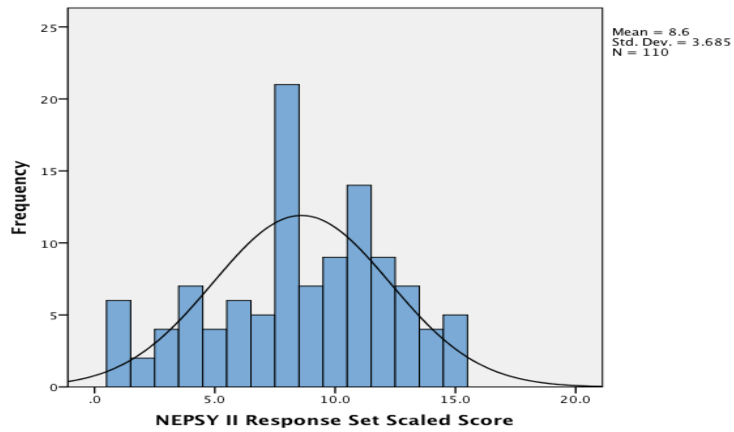

Figure 2i. Distribution of NEPSY-II Response Set Scaled Scores

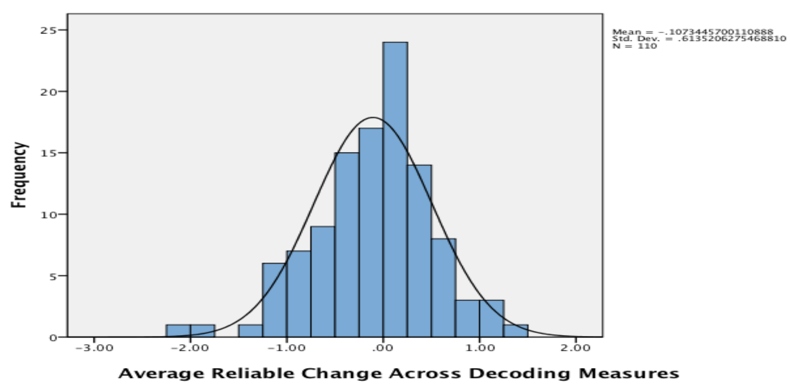

Figure 2j. Distribution of Reading Reliable Change Decoding Scores

Appendix B-Additional Tables

Table 5. *Spearman Correlations Among DBRS Scores, BRIEF Scores, DKEFS, NEPSY Subscale Scores, and Digit Span Backwards (N = 99)*

	RCI: Decoding	RCI: Text Reading	CTOPP -2 PA	DKEFS _CWI	DKEFS_ SO	DKEFS _TMT	DSB	BRIEF BRI	BRIEF MI	NEPSY -II AA	NEPSY -II RS
RCI: Decoding	---	$.40^{**}$	.04	.08	-.07	-.06	.10	.06	.03	.02	-.06
RCI: Text Reading	$.40^{**}$	---	.10	.16	.10	.03	.12	.08	-.04	.12	.18^
CTOPP-2 PA	.04	.10	---	.06	$.29^{**}$	$.29^{**}$	.08	$-.25^{*}$	-.16	.09	$.27^{**}$
DKEFS_ CWI	.08	.16	.06	---	.02	$.33^{**}$	.12	-.07	$-.20^{*}$	$.23^{*}$	.10
DKEFS_ SO	-.07	.10	$.29^{**}$	-.02	---	.18^	.05	-.13	-.10	-.02	.11
DKEFS_ TMT	.06	.03	$.29^{**}$	$.33^{**}$	.18^	---	.02	-.07	-.07	.10	$.27^{**}$
DSB	.10	-.12	.08	.12	-.05	.02	---	-.09	.18^	-.11	$-.24^{*}$
BRIEF BRI	.06	.08	$-.25^{*}$	-.07	-.13	-.07	.09	---	$.72^{**}$	>.01	.03
BRIEF MI	.03	-.04	-.16	$-.20^{*}$	-.10	-.07	.18^	$.72^{**}$	---	-.12	.03
NEPSY-II AA	.02	.12	.09	$.23^{*}$	-.02	.10	.11	>.01	-.12	---	$.51^{**}$
NEPSY-II RS	.06	.18^	$.27^{**}$	.10	.11	$.27^{**}$	$.24^{*}$	.03	.03	$.51^{**}$	---

***RCI: Decoding =** Average Reliable change index for decoding measures,* ***RCI: Text-Reading** = Average Reliable Change Index for Text-Reading Measures,* ***DKEFS_TMT =** DKEFS Trail Making Test,* ***DKEFS_CWI =**DKEFS Color Word Interference Test,* ***DKEFS_SO** = DKEFS Sorting Test,* ***BRIEF BRI** = BRIEF Behavioral Regulation Index,* ***BRIEF MI** = BRIEF Metacognition Index,* ***DBRS Inattention** = Disruptive Behavior Rating Scale Inattention Score (parent rated),* ***DBRS Hyperactivity** = Disruptive Behavior Rating Scale Hyperactivity Score (parent rated),* ***CTOPP-2 PA Composite** = Comprehensive Test of Phonological Processing Phonological Awareness Composite*