The Relation between Teacher Ratings of Attention and Executive Functioning with Reading Comprehension in Elementary School Students

by

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We acknowledge and respect the lək^{w}əŋən peoples on whose traditional territory the university stands, and the Songhees, Esquimalt and W̱SÁNEĆ peoples whose historical relationships with the land continue to this day.

Supervisory Committee

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Abstract

The purpose of the present study was to examine the associations among teacher ratings of attention deficit hyperactivity disorder (ADHD) symptomology and executive functioning (EF) skills with reading comprehension and its underlying components reflected in the Simple View of Reading (SVR) including decoding and language comprehension ability. A total of 27 second grade (n = 10), third grade (n = 12), and fourth grade (n = 5) students were recruited for the study. Standardized assessment measures were used to capture word reading, decoding, reading comprehension, semantics, grammar, listening, phonological processing, and working memory. Teacher questionnaires were used to assess ADHD symptomology and EF ability in participants. Correlation analyses were conducted to explore the associations among teacher ratings of EF and ADHD, reading comprehension, and its subskills outlined in the SVR. A series of hierarchical regression analyses were performed to identify whether teacher ratings of ADHD or EF added unique variance to reading comprehension after controlling for word level reading and language comprehension skills. Results from the current study give further support for the SVR as an effective model for conceptualizing reading comprehension. An association between EF difficulties and poor word reading, in addition to weaker reading comprehension skills, was identified. These findings highlight the need for further research examining the role that EF plays in reading comprehension and its underlying components in order to better support struggling readers.

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Dedication

I would like to thank my research supervisor, Dr. Gina Harrison, for her support during the completion of this research project. Her feedback and support helped me to gain proficiency in a variety of different skill sets related to conducting one's own research. Her ideas and perspectives, along with her expertise, helped me to think critically about the concepts covered in this project. I am also grateful to Dr. Jillian Roberts, whose feedback helped me grow as a learner and researcher, along with her consistent, positive support. I am very appreciative of the teachers, parents, and children of Northridge Elementary who were willing to participate in this study during a global pandemic. Their willingness to add additional responsibilities to their lives made this research project possible. I am also grateful to all of my friends and family, whose loving support has allowed me to challenge myself and accomplish my educational goals.

Introduction

Reading comprehension, the ability to process text and understand its meaning, is an integral component of academic achievement and everyday functioning (NRP, 2000). Reading deficits are particularly problematic for students, as they tend to persist over a student's education (Kiuru et al., 2013; Vellutino et al., 2004). While reading comprehension is defined in a variety of ways across the literature, it is generally understood to be a complex process in which language comprehension and word-level reading skills interact with one another to enable readers to comprehend text (Cain & Bignell, 2014; Gough & Tunmer, 1986; Perfetti & Stafura, 2014; Swanson et al., 2018).

Behavioural inattention is described as difficulties with organization, distractibility, attentional control, and remembering (American Psychiatric Association, 2013) and has been implicated in academic underachievement in the research (Cain & Bignell, 2014; Ferretti et al., 2019; Hinshaw, 1992). A negative correlation exists between teacher-reported classroom inattention, standardised academic test scores and academic performance outcomes for students across all ages (Gray et al., 2017). Symptoms of inattention include difficulty sustaining attention during tasks, making mistakes, difficulty listening when spoken to, and reluctance to engage in tasks that require sustained attention (American Psychiatric Association, 2013). These patterns of inattentive behaviour make it difficult for students to meet the demands of learning in typical classrooms and gain academic proficiency.

Several studies have examined the relation between reading ability and attention. Ratings of attention are related to listening comprehension, reading comprehension, and word reading skills (Cain & Bignell, 2014). In students with ADHD, comorbid rates of reading disabilities fall between 11% and 34% (DuPaul et al., 2013), indicating that students with ADHD are at a

heightened risk for developing a reading disability compared to their typically-developing peers. In a meta-analysis examining the correlation between academic performance deficits in participants with ADHD, the greatest impairment was found to occur in reading (d = 0.73) (Frazier et al., 2007). Poor attention has also been linked to deficits in updating working memory, a component of EF that is implicated in reading comprehension performance (Miller et al., 2013; Swanson et al., 2018) and the process that people use to consciously update task-relevant information for 10 to 15 seconds, before it is consolidated into short- and long-term memory (Miyake, 2000). Studies of attention and reading comprehension have failed to control for word-level reading and language comprehension ability, making it difficult to draw conclusions about the basis of reading comprehension deficits in students with heightened levels of inattention (Cain & Bignell, 2014). Despite the wealth of literature connecting attention to reading ability, less is known about whether the relation between attention and reading comprehension is mediated primarily by word reading difficulty, language impairment, or both, and to what extent EF deficits contribute to these associations.

Although theorists continue to explore the construct of EF, current models reliably indicate that this construct is comprised of cognitive capacities that include updating, shifting, and inhibition (Karr et al., 2018; Miyake, 2000) which are involved in goal setting, goal-directed planning and action, organizing, and performance monitoring (Jurado & Rosselli, 2007; Singer & Bashir, 1999). Related to the current study, research has observed that EF is predictive of reading comprehension (Cartwright et al., 2017; Follmer, 2018; Meixner et al., 2019). Some evidence suggests that EF may uniquely predict variability in reading comprehension beyond traditional predictors such as decoding and vocabulary skills (Cartwright et al., 2017). Nevertheless, more research is necessary to better understand these associations, and to what

extent attention mediates the association between EF and reading comprehension. The following section will define reading comprehension and the components underpinning this complex process. Next, attention is described and the literature examining the relation between attention and reading comprehension is reviewed. A discussion of EF processes and its association to attention and reading comprehension will follow. The purpose of the study and the research questions are outlined, followed by a description of the data analysis, and a summary of findings.

Reading Comprehension: A Multi-Componential Process

Reading comprehension is the process of simultaneously extracting and constructing meaning from written language. It is a cognitive activity which draws on multiple skills (Catts, 2018; Chiu, 2018; Vellutino et al., 2007). Reading comprehension requires adequate decoding ability, in addition to language comprehension for the understanding of text to occur (Hjetland et al., 2019). It is valuable to use a framework for examining complex processes such as reading comprehension because it sets out interconnected claims and assumptions that enable researchers to create theoretical models from which hypotheses can be developed and tested (Perfetti & Stafura, 2014). One model that has been influential in the conceptualization of reading comprehension is the Simple View of Reading (SVR), which describes reading comprehension as a product of decoding and language comprehension (Gough & Tunmer, 1986).

The SVR model describes two distinct constructs that explain the variance in reading comprehension ability: decoding and listening comprehension (Gough & Tunmer, 1986). Decoding refers to the ability to convert graphemes into phonemes and draws on phoneme awareness, letter knowledge, and word recognition (Gough & Tunmer, 1986). This construct is usually measured by word reading and pseudoword reading measures based on accuracy or speed (e.g. Miranda et al., 2017; Tomblin et al., 2000). The second component is language

comprehension, which draws on one's ability to process and comprehend orally presented information, tapping variations in vocabulary, listening comprehension, grammar, verbal working memory, and inference making skills (e.g. Babayiğit & Shapiro, 2019; Florit et al., 2014). According to the SVR model, language comprehension and decoding skills are necessary for comprehension of text because written letters must be translated into words represented in language, and the language must also be understood (Gough & Tunmer, 1986). Both decoding and linguistic comprehension are, although related, considered to be independent constructs, as both are predicted by different skill sets (Aouad & Savage, 2009; Kendeou et al., 2009). Phonological awareness and rapid automatized naming have both robustly predicted decoding ability (Moll et al., 2014; Plourde et al., 2018), whereas language comprehension is better predicted by syntactic understanding and vocabulary (Hagtvet, 2003).

According to the SVR, a skilled decoder draws on both word recognition and phonological awareness skills to read isolated words quickly and accurately (Gough & Tunmer, 1986). Decoding skills have been implicated in reading comprehension performance in the literature (e.g., Haft et al., 2019; Hagtvet, 2003; Slot et al., 2016; Wendling & Mather, 2009; Vellutino et al., 2004), although a meta-analysis of 110 studies conducted by García & Cain (2014) found inconsistencies across the research with regard to how much decoding predicts reading comprehension. The researchers found that age was a strong mediator in this association: as the age of participants increased, the link between decoding and reading comprehension decreased. Thus, evidence suggests that there are developmental differences in the magnitude with which decoding predicts reading comprehension, with higher associations in early development and lower associations later in development. In sum, as word reading becomes

more efficient, language comprehension skills become more influential. Nevertheless, decoding was strongly related to reading comprehension across all ages in the analysis.

Linguistic comprehension is the process by which oral information is interpreted (Gough & Tunmer, 1986). This process involves expressive and receptive vocabulary, inferential skills, grammatical and syntactic knowledge, and the ability to use context to understand oral information (Babayiğit & Shapiro, 2019; Florit et al., 2014). Linguistic comprehension has been implicated in the research as a strong predictor of reading comprehension (Babayigit; 2015; Babayiğit & Shapiro, 2019; Kendeou et al., 2009; Lervåg et al., 2018). Receptive language measures, in addition to syntactic knowledge and inference making, are often used in studies measuring oral language comprehension, although working memory tasks are also frequently used (e.g., Babayigit; 2015; Kendeou et al., 2009; Lervåg et al., 2018). Grammar, vocabulary, and inferencing ability are strong longitudinal predictors of both reading and listening comprehension (Lervåg et al., 2018). Although these components of language comprehension are distinct, research has found a significant correlation across these different skill sets (Cutting & Scarborough, 2006).

An abundance of research over the last several decades has supported the SVR theory as an effective model for describing the variance in reading comprehension (e.g., Aouad & Savage, 2009; Chiu, 2018; Colenbrander et al., 2016; García, & Cain, 2014; Hagtvet, 2003; Hjetland et al., 2019; Kendeou et al., 2009; Lervåg et al., 2018; Muter et al., 2004; Vellutino et al., 2007) although there is evidence that working memory (Cain et al., 2004; Swanson et al., 2018), fluency (e.g., Cutting & Scarborough, 2006), and naming speed are also predictive of reading comprehension (e.g., Joshi & Aaron, 2000; Plourde et al., 2018).

The variance in reading comprehension explained by the model has been measured at 48 % - 99 %, depending on the study (Hjetland et al., 2019; Joshi & Aaron, 2000; Lervåg et al., 2018), and has been replicated across reading comprehension measures (Babayiğit & Shapiro, 2019; Colenbrander et al., 2016). For example, Hjetland et al. (2019) conducted a 6-year longitudinal study of 215 monolingual Norwegian-speaking children beginning at age 4. The authors tracked the interrelation between factors predicting reading comprehension including language skills, decoding, and cognitive skills. Two pathways explaining the variation in reading comprehension were discovered. Part of the variance in reading comprehension was predicted by language comprehension, a construct captured by vocabulary, listening comprehension, grammar, and verbal working memory. The rest of the variance in reading comprehension performance was predicted through a code-related pathway which captured phoneme awareness, letter knowledge, and rapid automatized naming. Language comprehension in the early years was strongly correlated with code-related ability. Oral language skills in the early years also continued to predict reading comprehension levels throughout the study. Language comprehension and decoding ability explained almost all (99.7%) of the variance in reading comprehension at 7 years of age. As Norwegian is a semitransparent orthography, this may have impacted the significant amount of variance reported in this study. Orthographic transparency describes the consistency of correspondence between graphemes (letters or letter clusters) and phonemes (sounds) (Florit & Cain, 2014). In English, an opaque orthography, some graphemes can have multiple pronunciations, and some phonemes can be written in different ways. The effects of linguistic comprehension and decoding on reading comprehension varies depending on the transparency of orthography in which a child is learning to read, and for opaque orthographies such as English, word reading skills tend to develop at a slower rate (Florit &

Cain, 2014). Nevertheless, the SVR has been shown to be an effective model for conceptualizing reading comprehension even in English speaking children (Florit & Cain, 2014). In addition, a two year longitudinal study by Muter et al. (2004) which was conducted using English speaking children also found that word recognition skills (decoding and letter knowledge) and linguistic skills (vocabulary knowledge and grammatical skills) all played significant roles in explaining the variance in reading comprehension.

Some research has found a significant correlation between decoding ability and language comprehension tasks. Although researchers view these as separate constructs, some overlap in skill or ability may be present. For example, higher language ability tends to correlate with higher decoding skills in children (Hagtvet, 2003), and listening comprehension skills have been identified as a significant moderator that explains the association between reading comprehension and decoding (García & Cain, 2014). In contrast, in a longitudinal study by Kendeou et al. (2009), the authors found that regardless of age, decoding and oral language skills formed distinct clusters. The correlation between oral language and decoding was strongest in the pre-elementary cohort, and the relation became weaker in kindergarten and again in grade two. Both decoding and oral language independently predicted reading comprehension in grade two, supporting the theory that two distinct skill sets relating to reading comprehension are formed in the early elementary years.

Differences in measures of decoding, linguistic comprehension, and reading comprehension also influence the relation between these constructs (García & Cain, 2014; Hagtvet, 2003). Hagvet (2003) found that both oral and written language measures were moderately to highly correlated with reading comprehension measures, although this variance was influenced by the characteristics of the comprehension tasks. For example, when a reading

comprehension measure required the participant to retell aspects of the story, vocabulary and phonemic awareness, but not syntax, were correlated. However, in reading comprehension measures that use cloze tasks requiring students to fill in missing words from a passage, syntax and phonemic awareness were correlated, but not vocabulary. In addition, the correlation between decoding and reading comprehension appears to be higher when the measure for reading comprehension is narrative rather than expository, and lower when the participants are required to read the text aloud (García & Cain, 2014). This may be due to the fact that young readers often have well developed schemata of narrative texts, so decoding becomes a stronger predictor in reading comprehension compared to word knowledge (Best et al., 2008). Thus, the measure in which reading comprehension is captured has implications for research.

In summary, research supports SVR as a valid and influential model for understanding reading comprehension. Linguistic skills, in addition to word-level reading ability, interact to predict reading comprehension performance in students. Despite the fact that reading comprehension and attention have been linked in the research, it is not clear whether this is primarily the result of poor word reading skills or linguistic comprehension weaknesses (Cain & Bignell, 2014). The next section will review attention and its association with reading comprehension.

Definition of Attention

Attention is a multidimensional construct drawing on many processes, which makes it difficult to operationalize and measure (Fletcher, 1998). A popular model of attention discussed in the literature was posited by Posner and Peterson (1990) which includes three different networks: the alerting network (maintaining vigilance when completing a task), an orienting network (prioritizing relevant sensory input), and an executive network (often called focal

attention, which is conceptualized as the point in which a stimulus enters into one's conscious state) (Peterson & Posner, 2012).

The American Psychiatric Association (2013) defines behavioural inattention as difficulties with organization, distractibility, following directions, attending to relevant stimuli, and remembering. Symptoms of inattention fall along a spectrum, and is a phenomenon that is experienced by the general population at varying degrees (Groen-Blokhuis et al., 2014). When symptoms are severe, persistent over time, and impair a child's ability to function in daily life, these patterns of behaviour meet diagnostic criteria for ADHD. Diagnostic criteria for ADHD include symptoms of hyperactivity (excessive movement), impulsivity (acts before thinking or conscious judgement), and inattention (difficulty focusing) (American Psychiatric Association, 2013). Patterns of symptomatic behaviour are often captured using behavior rating scales which can be completed by teachers, parents, clinicians, and the individuals themselves.

Although often viewed as such in the literature, inattention is not a homogenous phenomenon. In one study of teacher-rated inattentive symptomatology, Święcicka and colleagues (2008) found five factors that influenced the expression of inattentive patterns of behaviour: withdrawal of attention, distractibility and tiredness, impulsivity and hyperactivity, high emotional control, and low emotional control. Analysis of the inattentive profiles of children from this study showed that attention disorders comprise at least two distinct categories of inattentive symptoms: distractibility and tiredness, and withdrawal of attention. These inattentive profiles interact with other learning difficulties which give rise to different patterns of inattention across individuals.

Developmental Trajectory in ADHD Symptomatology

Most research pertaining to attention examines students with ADHD or who are at-risk for the disability. Longitudinal research studies have provided evidence that inattention and hyperactivity-impulsivity symptoms relating to ADHD follow different developmental trajectories (Martel et al., 2016; Willcutt et al., 2012). In one study of 1,420 participants aged three to 36, Martel and colleagues (2016) found that across development, symptom structures became increasingly differentiated. Preschool aged children with ADHD tended to exhibit difficulties with attention, hyperactivity, and impulsivity. Impulsivity became more predominant in adolescence and, in adulthood, four clusters of symptomatology were found: mental effort, motor overactivity, disorganization, and verbal impulsivity. Despite these developmental changes, distractibility and difficulty sustaining attention appear to be core features of ADHD, regardless of development. Brocki & Bohlin (2006) found that poor inhibition (e.g. the ability to inhibit a powerful response or interrupt a current behavioural response) was most strongly related to ADHD in younger children, and poor functioning relating to complex executive functions (working memory and fluency) were more strongly associated with ADHD in older children.

For diagnostic purposes, the DSM-5 divides ADHD into three presentations: (a) predominantly hyperactive/impulsive presentation (b) predominantly inattentive presentation, and (c) combined presentation (American Psychiatric Association, 2013). Research suggests that these subtypes are often not stable over time, as inattention and hyperactivity follow different developmental trajectories (Willcutt et al., 2012). In a meta-analysis of 546 studies, Willcutt et al. (2012) found that preschool children who met criteria for ADHD predominantly hyperactive subtype displayed a decline in hyperactive behaviour through to age 9; however, ratings of

inattentive behaviour did not have a similar decline. While an ADHD diagnosis has adequate stability over time, presentation types tend to vary as hyperactivity-impulsivity symptoms decline more than inattention symptoms across development (Willcut et al., 2012).

Attention and its Relation to Academic Achievement

Inattention has been identified as a risk factor for poor academic achievement (American Psychiatric Association, 2018; Arnold et al., 2005; Hinshaw, 1992; Giannopulu et al., 2008; Maughan et al., 1996; Tomblin et al., 2000). A negative correlation exists between heightened levels of inattention as reported by teachers, and classroom performance and achievement on academic, standardized tests from preschool to high school (Gray et al., 2017). Interestingly, inattention, but not hyperactivity, has been implicated in predicting poor academic achievement in the research (Frick et al., 1991; Giannopulu et al., 2008; Massetti et al., 2008; Pingault et al., 2011; Sims & Lonigan, 2013). In a 15 year longitudinal study of 2,000 participants from a sample of Canadian children between the ages of six and 12 years, Pingault et al. (2011) found that high inattention during elementary school strongly predicted the likelihood of not having a high school diploma in early adulthood. Overall, the relation between hyperactivity–impulsivity and academic achievement is equivocal, but the link between inattention and learning problems has been thoroughly documented in the literature (Giannopulu et al., 2008).

Attention and its Relation to Reading Comprehension and its Underlying Components

Inattentive behaviour is correlated with poor reading comprehension (Cain & Bignell, 2014; Giannopulu, 2008; Jiang, 2018; Rabiner et al., 2000; Stern & Shalev, 2013) and has been shown to predict reading achievement even after controlling for IQ and other behavioural difficulties (Giannopulu et al., 2008; Rabiner et al., 2000). In one longitudinal study, one third of kindergarten students reading in the normal range with highly inattentive behaviours scored at

least one standard deviation below the mean in grade 5 on measures of reading comprehension (Rabiner et al., 2000), suggesting that inattention has long term negative consequences on academic performance.

Inattention has been found in the literature to have significant effects on early literacy skills in young children (Cain & Bignell, 2014; Costa et al., 2013; Martinussen et al., 2014; Giannopulu et al., 2008). These effects have even been measured in preschool aged children, where emergent literacy skills have been associated with attention levels across multiple methods of behavior assessment (Sims & Lonigan, 2013). In contrast, for adolescents from grade 7 to grade 12, decoding skills have not been shown to be as strong of a predictor for reading comprehension, regardless of attention profiles (Swanson et al., 2018). This is unsurprising because, as the SVR predicts, the relation between decoding and reading comprehension decreases as students age. As decoding becomes more efficient, language comprehension skills become stronger predictors of reading comprehension (García & Cain, 2014). In a longitudinal study, Dittman (2016) found that children's attentional focus on school entry predicted word reading at the end of grade 1. Inattentive levels in grade 1 contributed a small proportion of variance in word reading ability at the end of grade 2, although prior reading ability was the strongest predictor of future reading ability. Slow naming speed is significantly correlated with heightened levels of inattention, which is also strongly related to word-level reading ability (Martinussen et al., 2014). There is evidence to suggest that children with attention problems tend to have poor phonological processing at the phonemic level, which is also related to word reading ability (Costa et al., 2013; Martinussen et al., 2014; Plourde et al., 2018; Sims & Lonigan, 2013). In contrast, other researchers have found no link between attention and phonological processing (Dittman, 2016).

Language is an important component of academic and social success (Beitchman et al., 1990; Hinshaw, 1992; Tomblin et al., 2000) and weak attention has been linked to poor linguistic comprehension (Cain & Bignell, 2014; Gooch et al., 2019; McInnes, et al., 2003; Plourde et al., 2018). Most studies examining this correlation are conducted using participants with ADHD, and a link between ADHD and language comprehension deficits has been identified in the research (Korrel et al., 2017; Yochman et al., 2006). For example, children with specific language impairments (SLI) are more likely to display teacher-reported symptoms of ADHD than their peers, and students with SLI are more likely to have clinical levels of ADHD (Helland et al., 2016; Gooch et al., 2019; Tomblin et al., 2000). ADHD is also the most frequent psychiatric diagnosis for children that have language impairments (Cohen et al., 2000). These children are also significantly more likely to have a reading disability (Helland et al., 2016; Tomblin et al., 2000). Children with early language delays are more likely to demonstrate externalizing behaviour, particularly attention issues, and a large percentage of children with early language problems demonstrate subsequent underachievement (Hinshaw, 1992). In a meta-analysis of twenty-one studies examining the relation between SLI and ADHD using standardized measures, Korrell and colleagues (2017) found that students with ADHD scored more poorly on all 14 measures of expressive language, with correlation coefficients ranging from .32 to .87. The authors also found that children with ADHD performed significantly more poorly on measures of receptive language than controls. Interestingly, the presence of ADHD in students with comorbid SLI does not seem to further compromise listening comprehension ability beyond the influence of SLI alone (McInnes et al., 2003).

Vocabulary has been found to mediate the association between inattention and reading comprehension (Plourde et al., 2018; Swanson et al., 2018), although one study found that

teacher ratings of inattention in preschool children were not correlated with measures of vocabulary (Sims & Lonigan, 2013). Impaired inference-making abilities have also been found in students with ADHD (McInnes et al., 2003; Swanson et al., 2018). Children with ADHD seem to struggle more with making inferences from text and monitoring their comprehension rather than being able to recall facts (McInnes et al., 2003). In contract, some research found that the association between inference-making skills, vocabulary, and reading comprehension for adolescent readers was not dependent on inattentive or hyperactive profiles (Swanson et al., 2018).

Students with ADHD are at heightened risk for also having pragmatic language delays (Cohen et al., 2000; Helland et al., 2014; Helland et al., 2016; Korrel et al., 2017). In one meta-analysis, Green et al. (2014) found that children with features of ADHD have consistent profiles of pragmatic language impairments including poor conversational turn-taking, excessive talking, and lack of organization and coherence when speaking. Pragmatic language impairments have been shown to correlate with comorbid RD, SLI, and ADHD (Cohen et al., 2000; Helland, et al., 2014; Helland, et al., 2016).

In conclusion, research suggests that students with heightened levels of inattention are at risk for also having reading comprehension difficulties (Cain & Bignell, 2014; Giannopulu, 2008; Rabiner et al., 2000). Poor reading comprehension outcomes in these students have been connected to poor word-level reading skills (Costa et al., 2013; Martinussen et al., 2014; Plourde et al., 2018; Sims & Lonigan, 2013) and poor language comprehension (Cain & Bignell, 2014; Gooch et al., 2019; McInnes et al., 2003; Plourde et al., 2018). Inattention seems to negatively impact both decoding and language comprehension skills, particularly in younger students, two components necessary for reading comprehension based on the SVR. Inattentive symptoms

appear to interfere with cognitive processes required for learning, such as attending to instruction and information, which may affect the development of phonological awareness and vocabulary knowledge, leading to difficulties in decoding and reading comprehension (Plourde et al., 2018). The next section reviews research examining the association between EF, attention, and reading comprehension.

Definition and Models of Executive Function

Currently, there is no consensus on the definition of executive functioning (EF), but the term generally describes a broad range of higher order cognitive processes encompassing one's ability to enable flexible, goal-directed behavior (Castellanos et al., 2006), such as updating, shifting, and inhibition (Karr et al., 2018; Miyake, 2000). EF deficits impair an individual's ability to plan, organize, regulate emotion, initiate and inhibit action, respond flexibly, and utilize working memory, all processes that are important for academic and social success (Miranda et al., 2017; Zaleza et al., 2004). Higher levels of EF relating to inhibitory control correlates with improved adaptive functioning (task perseverance, learning, and pro-social behaviour), academic performance, fewer psychiatric symptoms, and higher attention in younger children (Vuontela et al., 2013).

Several theoretical models have been used to define EF in order to operationalize the construct in research studies. One influential model proposed by Denckla (1996) views EF as a non-unitary construct drawing on four domains: sustaining behavior, initiating behavior, inhibiting behavior, and set shifting. Miyake and colleagues (2000) model of EF reflects the most common conceptualization of EF: shifting of mental sets, response inhibition, and monitoring and updating working memory representations. The concept of working memory describes a system that stores and maintains information and is a component of human thought. The most

commonly conceptualized model for working memory includes four components: the central executive, the phonological loop, the visuospatial sketchpad, and the episodic buffer (Baddeley & Hitch, 1997; Baddeley, 2003). The central executive is an individual's general processing capacity, and is particularly concerned with attention (Baddeley, 2003). EF is relevant to this study because there is a lack of consensus across the literature on whether attention is an underlying component of EF or if it is a separate construct (Fletcher, 1998). By including a measure of EF in this study, the findings will help to illuminate whether EF ability or ADHD symptoms independently predict reading comprehension, and if the pathway between ADHD symptomatology and reading comprehension is better explained by a broader EF deficit.

Executive Function and its Relation to Reading Comprehension and its Underlying Components

Research has found that EF is predictive of reading comprehension (Cartwright et al., 2017; Follmer, 2018; Meixner et al., 2019). In a meta-analysis conducted by Follmer (2018), the author found a moderate positive association between EF and reading comprehension (r = .36). This correlation did not vary systematically according to age, EF measure, or reading comprehension measure. EF has been found to account for variance in reading comprehension beyond traditional predictors such as decoding and vocabulary (Cartwright et al., 2017; Nouwens et al., 2021). In addition, research has found that working memory explains unique variance in reading comprehension after word reading skills and verbal ability have been controlled for (Cain et al., 2004). Inhibitory processes have also been identified in the research to predict performance on reading comprehension measures (Borella et al., 2010). EF allows readers to integrate new ideas with prior knowledge, plan for comprehending text, inhibit irrelevant text or ideas during reading, process different components of text (meaning or context), and remember

relevant information (Follmer, 2018). EF is also associated with the underlying components required to comprehend text, including word reading ability and language comprehension (Gathercole et al., 2006; Jiang et al., 2018; Nouwens et al., 2021).

Working memory, a component of EF, has been implicated in language comprehension (Gathercole et al., 2006; Jiang et al., 2018). In a study of 370 students in grade one to three, Jiang and colleagues (2018) found that the association between working memory and reading comprehension was mediated partially through its influence on listening comprehension, and that working memory becomes more important as students age. In contrast, some research has failed to find a direct effect of EF on language comprehension (Nouwens et al., 2021).

EF has also been associated with word reading ability (Haft et al., 2019; Jiang et al., 2018; Nouwens et al., 2021). The influence of EF on reading comprehension has been found in some research to be partially mediated by its impact on word reading ability (Jiang et al., 2018). In contrast, some studies have found that EF is predictive of reading comprehension, but not of word reading skills (Sesma et al., 2009). Despite contradictory evidence on the impact EF has on the components of reading comprehension, research suggests that an individual's cognitive capacities are fundamental in developing literacy and language skills, and that EF skills are required for readers to both attend to text and utilize cognitive processes required for comprehension (Follmer, 2018).

Executive Function and Attention

Research has found that individuals with ADHD often have EF deficits (Castagna et al., 2019). In a meta-analysis of 83 studies, Willcutt and colleagues (2005) found that individuals with ADHD demonstrated significant impairments across all EF tasks. For all measures, effect sizes fell within the medium range (d=.46 to.69). The strongest effect sizes were found in

measures of response inhibition (stopping a motor response after an auditory cue and ignoring irrelevant information), vigilance (maintaining focus in order to respond to targeted sequences over a period of time), working memory (the storage and manipulation of information in memory), and planning (completing a task or goal while adhering to a set of rules). Weaknesses in EF in clinical and community samples were significant even after controlling for intelligence, academic achievement, and comorbid disorders. More contemporary research continues to find a connection between EF deficits and ADHD (Krieger & Amador-Campos, 2018).

An overlap between the concept of attention as a cognitive process and EF has prompted researchers to attempt to differentiate these two constructs and the measures used to capture them (Fletcher, 1998). Research has found a strong correlation between attentional focus and working memory, and has hypothesized that attention is directly linked to the storage and processing of information (Cowan et al., 2005). Regardless of how attention and EF are associated, it is apparent that attention is an important component in the execution of goal-orientated behaviour. Research has examined EF in children with ADHD and comorbid reading disabilities (RD). These students have a specific cognitive profile when compared to students with ADHD or RD alone, demonstrated by significant impairment in processing speed, retrospective memory, and response inhibition (Crippa et al., 2015).

In summary, students with EF deficits are at a greater risk for having RD (e.g., Cartwright et al., 2017; Follmer, 2018; Gathercole et al., 2004; Meixner et al., 2019; Swanson & Howell, 2001; Swanson & Jerman, 2009). Significant EF deficits have also been linked to ADHD across EF measures (Castagna et al., 2019; Willcutt et al., 2005). A link between attention and EF has been identified, although these constructs have not been adequately differentiated in the literature (Fletcher, 1998). Given the overlapping nature of EF and attention,

the findings of this study will help to illuminate the association between these two constructs, and how they relate to reading comprehension. The following section will address some theories that researchers have proposed to explain the patterns of comorbidity between RD and ADHD.

Explanations for Comorbidity

Several hypotheses have been put forward to explain the comorbidity between inattention and RD, although the research predominantly relates to ADHD. Theories supported by previous research of comorbid RD and ADHD include the phenocopy hypotheses (Pennington et al., 1993), the cognitive subtype hypothesis (Rucklidge & Tannock, 2002), and the common etiology hypothesis (Willcutt et al., 2000a; Willcutt et al., 2007). The phenocopy hypothesis suggests that one disorder may result in the symptoms of another disorder (Pennington et al., 1993). For example, patterns of inattention in students with reading disabilities are hypothesized to be a response to frustration associated with reading difficulty rather than as a result of the neurocognitive deficits typically associated with ADHD. Despite early findings, this theory has been largely unsupported within more current literature (e.g. Seidman et al., 2001; Willcutt et al., 2001).

The cognitive subtype hypothesis suggests that children with both ADHD and RD have a different or more severe form of ADHD or RD than children with either disorder alone. This theory has been supported in some research (Rucklidge & Tannock, 2002). In contrast, other researchers have found that individuals with ADHD and RD do not have a separate cognitive profile beyond the additive symptoms associated with ADHD and RD (Willcutt et al., 2005). It would be worthwhile for more research examining this hypothesis to be conducted.

The common etiology hypothesis proposes that etiological factors which increase the risk of one disorder also increase the risk for the other disorder. Twin studies examining the common

heritability of ADHD and RD found evidence to support this theory (Willcutt et al., 2000a; Willcutt et al., 2007). Genetic correlation is most prevalent for inattention and orthographic coding (e.g. the ability to hold in memory and recognize the correct spelling of a word), and lower for hyperactivity, impulsivity and phoneme awareness (Willcutt & Pennington, 2000). Comorbidity between RD and ADHD as a result of common genetic influences were also found in studies using bivariate twin analysis (Costa et al., 2013; Light et al., 1995; Willcutt et al., 2000b; Zumberge et al., 2007). Current research has found the strongest support for the common etiology hypothesis; the comorbidity of both disabilities is at least partially dependent on common genetic etiology. Nevertheless, the mechanisms relating to this shared genetic influence are still unknown (Willcutt et al., 2005).

The use of unidirectional, 'main effects' models to explain the comorbidity of inattention and RD are unlikely to do a sufficient job of explaining this link. Different sub-groups of individuals are likely to be more or less influenced by different factors throughout a child's development (Maughan et al., 1996). The comorbidity of ADHD and academic underachievement are influenced by interrelations of linguistic, social, and early familial variables (Hinshaw, 1992). Low socioeconomic status, family adversity, sub average IQ, language deficits, and neurodevelopmental delay may all influence the development of the comorbidity of underachievement and behaviour disorders, but each factor may predispose some children to both disorders (Hinshaw, 1992).

In summary, while there have been many theories to explain the association between ADHD and RD, there is no common consensus in the literature. By examining the associations between teacher ratings of ADHD, EF, and reading comprehension, this study will add to the current body of literature reporting on how these constructs interact with one another. While the

goal of this study is not to identify pathways of co-morbidity, it is hoped that the findings will provide additional information to future researchers examining this topic. The next section will review the challenges associated with researching reading comprehension, ADHD symptoms, and EF.

Methodological Problems in the Assessment of Reading Comprehension, ADHD, and Executive Function

There is no single theory of reading because reading consists of too many components for a single theory to encapsulate. There are theories that explain word reading, theories of reading comprehension, theories of learning to read, and theories of dyslexia for the purposes of targeting and measuring a manageable component of reading (Perfetti & Stafura, 2014). Given the complex processes that are tapped by various aspects of reading reflected in reading theories, it is not surprising that many commonly used tests of reading comprehension may not measure the same cognitive processes (Cutting & Scarborough, 2006).

Reading comprehension tests tend to vary markedly in both task demands and conceptual framework, and emphasis on bottom-up (decoding) and top-down (linguistic) factors may not be consistent across measures. Different assessments may also vary in the demands they make on sentence-processing abilities and vocabulary knowledge (Cutting & Scarborough, 2006). Differences in expository versus narrative text have also been found to influence the amount of variance that decoding predicts in reading comprehension (García & Cain, 2014). In addition, decoding has also been found to account for more variance in comprehension when cloze tasks are used rather than question and answer tasks (Cutting & Scarborough, 2006). Other factors that influence the variability of reading comprehension scores across measures consist of word frequency, syntactic complexity, passage length, and whether readers can review the text when

answering questions, which draws on different memory demands (Cutting & Scarborough, 2006). These are important considerations given that the present study is designed to parcel out how symptoms of ADHD and EF impact decoding and linguistic comprehension when predicting reading comprehension. For example, if a reading comprehension measure were to draw heavily on top-down skills, language deficits may have a greater impact on reading comprehension scores, thus falsely inflating the magnitude that language comprehension has on reading comprehension. Nevertheless, standardized reading comprehension measures reflect common reading comprehension assessment practices typical of a classroom.

There are conceptual problems associated with researching ADHD symptoms as well. In a review of attention and its relation to academic achievement, Gray et al. (2017) found significant variation across studies. The discrepancy between studies was attributed by the authors to the separation or joining of inattentive and hyperactivity/impulsivity dimensions, age of participants, factors of comorbidity, control factors, as well as measures of behaviour and academic achievement.

One conceptual problem in assessing ADHD symptoms and EF is that there is no clear consensus on whether difficulties with attention that are often prevalent in those with ADHD should be conceptualized and measured as a separate process or as an underlying component of EF, given the interrelatedness of these constructs (Klenberg et al., 2001). For example, some evidence has found that working memory capacity and other EF components rely on an underlying executive attention ability, and that attentional focus is required for successful performance on EF tasks (McCabe et al., 2010). From a review of the literature pertaining to attention, Petersen and Posner (2012) offer an updated model of their executive control network which was first proposed as a component of attention in 1990. The authors made the argument

for two separate executive control networks that work relatively independently of one another: a cingulo-opercular control system required for the maintenance of task performance, and the frontoparietal system, involved in task switching and initiation (Peterson & Posner, 2012). This theory of attention mirrors the concept of shifting reflected in current models of EF (Karr et al., 2018; Miyake, 2000). Thus, the level of distinction between ADHD symptoms and EF is dependent on the framework researchers use to conceptualize these concepts. This has implications for how these constructs are measured and the conclusions drawn from research investigating these constructs.

There are challenges associated with assessing EF that have implications for research and data interpretation. One common problem identified in the literature is the "task impurity problem" which describes the fact that executive tasks implicate other non-executive cognitive abilities (e.g. verbal ability or motor speed), and often draw on more than one EF process. Given that EF tasks are multi-cognitive, performance on a task should not be viewed as a discrete measure of an executive ability (van der Sluis et al., 2007). In addition, general intelligence shares a significant amount of variance with EF, making the theoretical framework behind EF that much more challenging. More information is needed to distinguish the link between these constructs (Davis et al., 2011). In addition, how EF is measured also has implications for research. In reviewing literature investigating EF and reading comprehension, EF is captured primarily by performance-based measures rather than rating scales. Although both performance-based measures and rating scales of EF are designed to capture the same construct, some research suggests that they are only minimally correlated (Toplak et al., 2013). This finding has implications for conclusions drawn by studies utilizing only one method of measuring EF and when comparing findings across the literature.

Executive Summary and the Present Study

Reading comprehension is a complex process drawing on word-level reading and language comprehension skills (Gough & Tunmer, 1986). Research suggests that heightened levels of inattention are correlated with poor reading comprehension performance (Cain & Bignell, 2014; Ferretti et al., 2019; Hinshaw, 1992; Swanson, et al., 2018; Willcut & Pennington, 2000). EF difficulties have also been implicated in reading comprehension challenges (Cartwright et al., 2017; Follmer, 2018; Meixner et al., 2019), and are often evident in children who have ADHD (Castagna et al., 2019; Krieger & Amador-Campos, 2018; Willcutt et al., 2005). The purpose of the present study was to examine the associations among teacher ratings of EF and ADHD symptoms, along with reading comprehension and its subskills outlined in the SVR. In addition, this study examined the contribution that teacher ratings of ADHD and EF had in predicting reading comprehension within the SVR model.

Examining the link between teacher ratings of ADHD, EF, and reading comprehension in grade two to four students is appropriate and timely, as word-level decoding skills tend to be better predictors of students in younger students (García & Cain, 2014), but participants should have gained enough reading related skills for reading comprehension to take place. Patterns of attention tend to be stable over time (Martel et al., 2016), so measuring attention in elementary school-aged children is also developmentally appropriate. The examination of these constructs is relevant to educational psychology as this research will expand the current understanding of how EF and ADHD symptoms impact reading comprehension in young students in order to improve early identification and effective reading and behaviour interventions. In addition, findings help shed light on the components of reading comprehension in elementary school-aged children to inform current models of reading comprehension.

The present study addressed the following research questions: a) What are the associations among teacher ratings of ADHD, EF, and reading comprehension in second to fourth grade students? b) Do teacher ratings of ADHD or EF add unique variance in predicting reading comprehension performance after controlling for word-level reading and language comprehension ability? c) How do the language and reading profiles of children with EF deficits differ from children with typically developing EF?

Given the current literature on the subject, it was hypothesized that higher teacher rated levels of ADHD symptoms and EF difficulties would correlate with poorer word-level reading skills, language comprehension ability, and reading comprehension performance. It was also hypothesized that ratings of EF would strongly relate to ratings of ADHD. The next section describes the methods of the current study.

Methods

This study examined the associations between teacher ratings of EF skills and symptoms of ADHD to component skills of reading comprehension in students nearing the end of second to fourth grade. The present study explored the associations between word-level reading skills, expressive and receptive language, reading comprehension performance, and teacher ratings of EF and ADHD in the participant sample. A cross-sectional, nonexperimental, single-group research design was used to collect and analyze data on 27 participants within a 2-month time span. Data was collected from the beginning of March through to the end of April of the academic year on students in the Greater Victoria School District.

Participants

A total of 27 students in second grade (n = 10; male: 5, female: 5), third grade (n = 12; male: 3 female: 9), and fourth grade (n = 5; male: 3; female: 2) from Greater Victoria served in

general education classrooms participated in this cross-sectional study. Participants were recruited from four different classrooms from one school in the district. No measure of participants' SES was used in this study, however, the participants came from a predominantly Caucasian, middle class community. Teachers were asked to only nominate children with no history of intellectual, motor, or developmental disabilities, uncorrected visual or hearing deficits, or who were English Language Learners. Four participants were receiving learning support for reading and writing difficulties.

Sampling Procedure

The principal of one school in the Greater Victoria School District was approached in order to receive permission to conduct this study in their school. Once permission was given, the grade two, three and four teachers were asked to participate in the study on behalf of themselves and their students. A description of the study, along with a parent consent form, was sent home to parents of students who did not meet any of the exclusion criteria. Approximately 34% of the sample that was approached participated in the study.

Sample Size and Power

The initial aim of this study was to have a sample size of 45 participants to ensure sufficient statistical power to detect small effect sizes. Primarily due to conducting this study during the COVD-19 pandemic, finding participants proved to be challenging. Consequently, a sample of 27 participants was used. For the correlation analysis, there was a statically power of 0.71 to detect an effect size of 0.3 and a power of 0.77 to detect an effect size at 0.15 for the three variable hierarchical linear regressions.

Measures

All measures used in this study were normed on English-speaking populations and were remotely administered according to the standardized procedures described in the test manuals through an online video communications platform. For all participants, the assessments took place in their homes, and for the majority of the participants, in a room alone by themselves.

Reading comprehension. The Reading Comprehension subtest of the Wechsler Individual Achievement Test-Third Edition (WIAT-III; The Psychological Corporation, 2002) was administered to collect data on reading comprehension ability. The WIAT-III is a standardized, norm-referenced achievement measure. Reading comprehension was assessed by orally posing questions about passages that are read by the participant either silently or aloud. Questions related to the content of text (e.g. main idea, story details), inferences that could be drawn from the story's content, and the definition of words within the text. During administration, participants were permitted to refer to the text while answering the questions. Basal and ceiling rules were utilized in this measure. The internal consistency reliability alpha coefficient ranged from .85 to .91 for students in grade 2 through grade 4. This subtest has been used in the research literature as a measure of reading comprehension (Altemeier et al., 2008; Garcia & Cain, 2014; Sesma et al., 2009).

Word Reading. Word reading accuracy was measured using the Word Reading subtest of the WIAT-III (The Psychological Corporation, 2002). This untimed subtest required participants to accurately name letters and basic words from a graded word list. Basal and ceiling rules were utilized according to the test manual. The internal consistency reliability alpha coefficient ranged from .97 to .98 for the age of the participants in this study. This subtest has

been used to assess word recognition in other studies investigating reading ability (Altemeier et al., 2008; Sesma et al., 2009).

Decoding. Decoding ability was assessed using the Pseudoword Decoding subtest of the WIAT-III (The Psychological Corporation, 2002). Previous studies have also used this measure as a test of phonological ability (Altemeier et al., 2008). For this untimed subtest, the participant was given a list of non-words which they attempted to pronounce accurately according to English phonetic rules. Basal and ceiling rules were utilized according to the test manual in this measure. The internal consistency reliability alpha coefficient ranged from .96 to .97 for participants.

Attention. Attention was measured using the ADHD Rating Scale - 5 for Children and Adolescents. The ADHD Rating Scale - 5 is a questionnaire that rates home behaviours on the parent questionnaire and classroom behaviours on the teacher questionnaire. The School Version was utilized in this study. Questions are keyed to DSM-5 diagnostic criteria for ADHD. Two symptom subscales are captured in both versions: Inattention (nine items) and Hyperactivity–Impulsivity (nine items). Internal consistency was high; alpha coefficients ranged from .89 to .96 for this age group. Test–retest reliability over approximately six weeks ranged from .90 to .93 for the School version.

Executive Functioning. EF was assessed using the Behavior Rating Inventory of Executive Function, Second Edition (BRIEF 2). The BRIEF 2 is a norm-referenced questionnaire that assesses EF in children ages five to 18 years. The measure reports on three indexes composed of behavior regulation, emotion regulation, and cognitive regulation. Parent, teacher, and self-report forms are available, but only the Teacher Form was used in this study. The BRIEF 2 contains 63 questions using a 3-point Likert-type scale ranging from N (never a

problem) to O (often a problem). Examples of questions relating to emotion regulation are “has explosive, angry outbursts” or “becomes upset too easily”. Examples of questions measuring behaviour regulation are “acts too wild or out of control” or “has trouble putting the brakes on his or her actions”. Examples of questions relating to cognitive regulation are “does not check work for mistakes” or “has problems coming up with different ways of solving a problem”. Administration time for the BRIEF 2 was roughly 5 minutes. The internal consistency reliability alpha coefficient for this age demographic ranged from .97 to .98. This measure has been used to assess EF in other studies (Mahone et al., 2002), and was reported as the most common rating scale used to measure EF in a literature review (Toplak et al., 2013).

Language Comprehension. To assess expressive and receptive language, the Test of Language Development-Primary: Fifth Edition (TOLD-P:5) and the Test of Language Development-Intermediate: Fourth Edition (TOLD-I:4) were used. Two subtests were administered. The Picture Vocabulary subtest measured semantics and listening by requiring the participant to point to the picture that represented the word spoken allowed by the examiner. The coefficient alpha for internal consistency for this subtest was between .85 to .96 for this age group.

The Syntactic Understanding subtest required the participant to point to the picture that best represented the sentence spoken aloud by the examiner and was a measure of grammar and listening. The internal consistency coefficient alpha for this subtest fell between .82 and .83 for participants. Administration time was approximately 10 minutes. Older versions of the Test of Language Development have been used in other research (Korrel et al., 2017; Laurie et al., 2009)

Working memory. The Digit Span Backward (DSB) test of the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV; Wechsler, 2003), was administered to assess

verbal working memory, and is a widely used measure in the literature of educational psychology (Cutting et al., 2009). The DSB required participants to listen to a string of numbers that increase in length, and to repeat those numbers in reverse order, to the administrator. Starting and stopping rules for this subtest were based on the basal and ceiling rules described in the test manual. The internal consistency reliability alpha coefficient ranged from .78 to .86 for this age demographic.

Phonological Processing. The Elision subtest from the Comprehensive Test of Phonological Processing - Second Edition (CTOPP-2) was administered to capture phonological processing. Subtests from the CTOPP-2 are often used in research examining oral language (Conner et al., 2019; Cutting & Scarborough, 2006). The Elision measured the participants ability to remove phonological segments from spoken words to form other words. Stopping rules for this subtest were based on the basal and ceiling rules described in the test manual. The internal consistency coefficient alpha for this subtest was .89 for this age group.

Rapid Letter Naming. The Rapid Letter Naming subtest from the CTOPP-2 captured the participant's ability to rapidly name letters in a row. The participant was shown four rows of letters and was asked to name the letters as quickly and accurately as possible. This measured the participant's ability to efficiently retrieve phonological information from memory and execute a sequence of operations with speed and accuracy. Starting and stopping rules for this subtest were based on the basal and ceiling rules described in the test manual. The test-retest reliability for this age group was above .80.

Procedures

Participants completed all measures individually, at their homes, outside of school hours, through Zoom, an online video communications platform in one 45 to 60 minute session. The reading subtests of the WIAT-III were administered first, followed by measures on the CTOPP-2, TOLD-P:5 and TOLD-I:4; then the Digit Span Backwards test. Teachers filled out both the BRIEF 2 and the ADHD Rating Scale - 5 at their convenience. Data was collected by the author of this study after permission to conduct this research was given by the Human Research Ethics Board at the University of Victoria and by the Greater Victoria School District.

Results

For each measure, raw scores were converted to standard scores (M = 100; SD = 15). In all analyses, no data was missing and all participants were included. Outlier scores identified in the preliminary analyses were examined, but retained as the data points captured variation in participant ability, rather than measurement error. As a consequence of the small sample size, some variables did not meet assumptions for normality. Small sample sizes are sensitive to extreme scores, increasing the likelihood that variables will not meet assumptions of normality or freedom from outliers (Brace et al., 2013). Parametric tests were used despite some variables not meeting parametric assumptions because parametric tests are still effective for non-normal data when the sample size is above twenty (Minitab, 2015). Linear regression assumptions were met, including normally distributed range of residuals and normality of the dependent variable. Assumptions of absence of collinearity were met as none of the tolerance values fell below .20. For all regression analyses, Durbin-Watson's d test fell between 1.5 and 2.5, indicating an absence of autocorrelation. Variance of residuals were examined using q-q plots and histograms, confirming that residuals were constant, meeting assumptions of homoscedasticity.

Descriptive results are presented in Table 1. No statistically significant variations between gender means were found across variables. A t-test was run for those variables meeting t-test assumptions. A Mann-Whitney U test was run for teacher ratings of ADHD and EF, Rapid Letter Naming, Reading Comprehension, Pseudoword Reading, and Syntactic Understanding to identify any gender differences in these variables. Mean performance on all measures fell within age level expectations. Results of the correlation analysis is discussed next.

Table 1 - *Descriptive statistics across measures*

Measure	M	(*SD*)	Min.	Max.
Age in months	102.7	*(8.48)*	89	119
Elision (CTOPP-2)	97.59	*(10.69)*	80	115
Rapid Letter Naming (CTOPP-2)	92.96	*(7.88)*	85	115
ADHD Rating Scale (ADHD Rating Scale - 5)	94.3	*(15.87)*	67	129
EF Rating Scale (BRIEF 2)	99.84	*(16.22)*	83	140
Digit Span Backwards (WISC-IV)	99.26	*(13.5)*	75	130
Reading Comprehension (WIAT-III)	92.96	*(11.84)*	67	116
Word Reading (WIAT-III)	101.81	*(15.54)*	72	132
Pseudoword Decoding (WIAT-III)	98.22	*(14.37)*	73	130
Picture Vocabulary (TOLD-P:5/TOLD-I:4)	97.96	*(15.27)*	60	125
Syntactic Understanding (TOLD-P:5)	110.00	*(15.44)*	50	130
Word Reading Composite	100.02	*(14.39)*	76	128.5
Language Comprehension Composite	103.98	*(12.52)*	72	122.5

Note. With the exception of age, all other values are presented in standard scores.

Correlations between Reading Comprehension and Ratings of Executive Function and ADHD

Correlation analyses using Pearson product correlations were conducted to address the first research question, seeking to examine associations among reading comprehension performance, word recognition, word decoding, vocabulary, syntactic understanding, and teacher ratings of EF and ADHD symptomology. The Pearson's correlation coefficients are reported on Table 2. As high scores on the teacher ratings of EF and ADHD represent higher rates of ADHD symptoms and weaker EF, negative correlational values indicate that a higher rating of problems across scales are associated with lower scores on the reading and language variables. Reading comprehension was found to have significant and large positive correlation with performance on all word-level reading tasks, with correlation coefficients ranging from $r = .733$ to $r = .637$, and a moderate positive correlation with syntactic understanding ($r = .41$, $p = .034$) and receptive vocabulary ($r = .37$, $p = .061$), although the later was not statistically significant. As expected, pseudoword decoding and word reading were highly correlated ($r = .85$, $p < .001$).

As shown on Table 2, reading comprehension performance was moderately and negatively correlated with teacher ratings of EF ($r = -.439$, $p = .02$), indicating a negative association between higher rates of EF difficulties identified by teachers and lower reading comprehension scores. Reading comprehension performance was moderately correlated with scores on the Elision ($r = .32$, $p = .17$) and teacher ratings of ADHD symptoms ($r = -.37$, $p = .06$), but none were statistically significant likely due to the power of the study. Higher rates EF difficulties were associated with higher levels of ADHD symptoms as rated by teachers ($r = .866$, $p < .001$). Higher rates of EF difficulties were moderately to highly negatively correlated with word-level reading ability with correlation coefficients ranging from $r = -.536$ to $r = -.414$. In other words, higher rates of teacher-rated EF difficulties were associated with lower word-

level reading scores. Higher teacher ratings of ADHD symptoms were moderately negatively correlated with weaker word reading skills (r = -.41, p = .035) and pseudoword reading (r = -.36, p = 0.6), although the later was not statistically significant. Teacher ratings of EF and ADHD symptomology were not significantly correlated with any language comprehension variable or the Digit Span Backwards subtest, but a small effect size was found between both variables and Rapid Letter Naming, with effect sizes from -.26 to -29. Neither correlation was statistically significant.

Table 2
Pearson's correlation coefficients among ratings of EF, ratings of ADHD, and reading measures (N = 27)

Measure	1	2	3	4	5	6	7	8	9	10
1.) Reading Comprehension	-									
2.) Pseudoword	.64**	-								
3.)Word Reading	.73**	.85**	-							
4.) Syntactic	.41*	.22	.22	-						
5.) Picture	.37	.27	.30	.33	-					
6.) RLN	.07	.02	-.07	-.41*	-.16	-				
7.) Elision	.32	.63**	.50**	.02	-.24	.02	-			
8.) ADHD Rating	-.37	-.36	-.41*	-.02	.07	-.29	-.23	-		
9.) EF Rating Scale	-.44*	-.41*	-.54**	.06	.10	-.26	-.20	.89**	-	
10.) DSB	.24	.21	.24	.27	.07	-.52**	.27	.06	.01	-
Measure	1	2	3	4	5	6	7	8	9	10

**p < .05.*
***P < .01.*

Predictors of Reading Comprehension

To address the second question of whether or not teacher ratings of ADHD symptomology or EF skills predicted reading comprehension performance after controlling for word reading and language comprehension ability, a series of hierarchical regression analyses

were performed. A composite word-level reading score was computed using scores from the WIAT-III Pseudoword Decoding and Word Reading subtests. The composite score is derived from the mean performance on both subtests. A composite language comprehension score was also computed using the mean performance on both the Picture Vocabulary and Syntactic Understanding subtests of the TOLD P:5 and the TOLD I:4. These two composite scores were used in the subsequent regression analyses.

The first regression analysis examined the unique variance teacher ratings of ADHD had in predicting reading comprehension. Guided by the SVR model, word-level reading skills were entered into step one of the model, followed by language comprehension at step two. Teacher ratings of ADHD symptoms were added at step three. Table three presents a summary of the regression analysis. Model 1, with word-level reading scores as the only predictor, explained 49% of variance and was a significant predictor in reading comprehension ($F(1,25) = 26.02$, $p < .001$), as expected. The addition of the language comprehension composite variable added 6.8% of the variance in reading comprehension, but was not statistically significant ($F(1,24) = 3.85$, $p = .06$). It is worth noting that this finding approached significance but was constrained by a lack of power. Including teacher ratings of ADHD symptoms in the final step added a further 1.9% of variance in reading comprehension, but was also not statistically significant ($F(1,23) = 1.085$, $p = .31$).

A second regression analysis was conducted to examine whether teacher ratings of EF skills contributed unique variance in reading comprehension performance after controlling for word-level reading ability and language comprehension. As above, word-level reading skills were added in step one of the model, followed by language comprehension scores in step two, and the teacher ratings of EF skills in step three. Table three presents a summary of the

regression analysis. Similar to the previous regression analysis, Model 1, with word-level reading as the only predictor, explained most of the variance (49%) and was statistically significant ($F(1,25) = 26.02$, $p < .001$). The addition of the language comprehension composite variable added 6.8% of variance in reading comprehension performance, and although approaching significance was not statistically significant (F (1,24) = 3.85, p = .061). Adding teacher ratings of EF skills in the final step contributed a further 3.5% of variance in reading comprehension, slightly more than teacher ratings of ADHD, but was also not statistically significant ($F(1,23) = 2.098$, p = .161).

Table 3
Summary of three multiple regression analyses predicting reading comprehension

Step & Predictor	ΔR ²	ΔF	β
1.) Word Reading Composite Score	.51**	26.02**	.71**
2.) Language Comprehension Composite Score	.07	3.85	.28
3.) ADHD Rating Scale	.02	1.09	-.15

Step & Predictor	ΔR ²	ΔF	β
1.) Word Reading Composite Score	.51**	26.02**	.71**
2.) Language Comprehension Composite Score	.07	3.85	.28
3.) EF Rating Scale	.04	2.10	-.23

Additional Analysis: Reading Profiles of Students at-risk for Executive Functioning Impairment

According to the BRIEF 2 Professional Manual (2015), children with *T* scores above 65 may be at-risk for disorders associated with difficulties in EF, including ADHD and Autism Spectrum Disorder. Four participants in this study fell above this diagnostic cut-off range. Three of these participants were male, and one participant was female. Two of these participants were in grade 4, and two participants were in grade 2. Unsurprisingly, these students also scored in the high average range or above on the ADHD-5 rating scale measuring ADHD symptomology. These participants' reading profiles are reviewed in the following section.

Contrary to the hypothesis outlined in this study, only two of the four participants fell below the average range on the Reading Comprehension measure. One of these participants (male, grade 2) scored well below the average range in reading comprehension performance (SS: 67). This participant scored in the high average and average range for the Syntactic Understanding subtest (SS: 115) and the Picture Vocabulary subtest (SS: 110). Performance on the Word Reading subtest also fell well below the average range (SS: 73), and performance on the Pseudoword Decoding subtest fell in the low average range (SS: 85). The participant's scores for both phonological processing subtests (Elision and Rapid Letter Naming) fell in low average range (SS: 85), and in the below average range for the Digit Span Backwards subtest (SS: 80).

A second participant (female, grade 2) had high teacher ratings of difficulties with EF and a Reading Comprehension score that also fell below the average range (SS: 83). This participant scored in the well below average range for Pseudoword Decoding (SS: 79) and the low average range for Picture Vocabulary (*Z*: 85), but scored in the average range for the other word reading and language comprehension measures. Scores on Rapid Letter Naming and

Elision subtests fell in the average range, and high average range for the Digit Span Backwards subtest (SS: 115).

The third participant (male, grade 4) scored in the average range for Reading Comprehension (SS: 97), Digit Span Backwards (SS: 100), Rapid Letter Naming (SS: 95), below average on Psuedoword Decoding (SS:84) and the Elision (SS: 80), and well below average for Word Reading (SS: 79). Both language comprehension measures fell in the above average range. The fourth participant (male, grade 4) scored in the average range for all subtests except for Picture Vocabulary, which fell within the low average range (SS: 85).

In summary, these profiles suggest that teacher ratings of EF difficulties do not consistently relate to reading comprehension deficits, as only two of the four participants experienced challenges in reading comprehension. Instead, reading comprehension deficits appear to have more to do with difficulties in the underlying components of reading comprehension outlined in the SVR, particularly word-level reading skills. It is likely that EF deficits impair one's ability to gain mastery in these subskills (Gathercole et al., 2006; Haft et al., 2019; Jiang et al., 2018), but to what extent difficulties with EF relate to word-level reading and language comprehension ability varies across individuals.

Discussion

The present study examined the associations between reading comprehension, teacher ratings of EF and ADHD symptoms, and the components of reading comprehension in English native speaking students in grades two to four. This study sought to add further knowledge to the limited body of research examining the influence that EF skills and ADHD symptomology have on the components of reading comprehension reflected in the Simple View of Reading. The next

section will discuss findings pertaining to the research questions, and implications and limitations of the present study.

The Association of Reading Comprehension, Executive Function, and ADHD Measures

The first research question presented in this study sought to examine the associations among reading comprehension, teacher ratings of ADHD symptoms and EF skills, word reading skills and language comprehension ability. As predicted, and consistent with the SVR, word reading skills were found to be significantly associated with reading comprehension performance. Similar findings are reflected in the literature (e.g., Haft et al., 2019; Hagtvet, 2003; Slot et al., 2016; Wendling & Mather, 2009; Vellutino et al., 2004). A strong association between language comprehension and reading comprehension is also reported in the literature (Babayigit; 2015; Babayiğit & Shapiro, 2019; Kendeou et al., 2009; Lervåg et al., 2018). In the present study, there was a moderate association between language comprehension measures and reading comprehension, with syntactic understanding skills reaching statistical significance. Similar findings are replicated in other research (Deacon & Kieffer, 2018). In addition, research suggests that components of language comprehension are distinct, but that there are often significant correlations across components (Cutting & Scarborough, 2006). A moderate association was found between syntactic understanding and vocabulary, but was not statistically significant. Implications for the lack of statistically significant findings between the language comprehension measures and other variables captured in this study are discussed later in this paper. Consistent with other research reporting that the SVR is an effective model to conceptualize reading comprehension (Aouad & Savage, 2009; Chiu, 2018; Colenbrander et al., 2016; García, & Cain, 2014; Hagtvet, 2003), this study found associations between word-level reading skills and language comprehension to reading comprehension.

In some research investigating the association between decoding ability and language comprehension performance, evidence suggests that higher decoding skills are associated with higher language comprehension ability (Hagtvet, 2003). Small correlations were found between word-level reading measures and language comprehension measures in the present study, although the values did not reach statistical significance. Despite associations between these skills identified in some research (Hagtvet, 2003), both have been found to independently predict reading comprehension (Kendeou et al., 2009; Muter et al., 2004). Evidence from this study supports the theory that language comprehension and word-level reading represent two distinct capacities. Scores on both word-level reading subtests had a moderate to large correlation with scores on the Elision, as these skills are more closely associated with phonological awareness (Willcutt et al., 2001) rather than language comprehension.

Possible explanations for the failure of this present study to identify a statically significant, but relatively modest in magnitude (.37), correlation between the vocabulary measure and reading comprehension performance, in addition to the lack of statistically significant correlations across both language measures and word reading tasks, is likely the result of the lack of power in the current study's design. Small sample sizes can make it more challenging for parametric tests to identify associations among variables, as outliers and small fluctuations in data can have a significant effect on findings. With a larger sample size, correlations may have reached statistical significance. In addition, the measures involved in capturing language comprehension and the assessment procedure may have influenced findings. For example, many studies examining language comprehension also assess grammatical skills and listening comprehension, in addition to syntactic understanding and receptive language (e.g., Babayiğit & Shapiro, 2019; LARRC, 2017; Lervåget al., 2018; Nation et al., 2004). Drawing on a wider

variety of language comprehension variables tapping different components of language comprehension may have helped to better illuminate the associations between these constructs. Finally, while both language measures report high internal consistency alphas, these were calculated using data collected from in-person assessment administration. By conducting these assessments remotely, administration may have impacted the validity and reliability of these scores.

A relation between working memory and reading comprehension is reported in the research (Cain et al., 2004; Swanson et al., 2018), along with naming speed (Joshi & Aaron, 2000; Plourde et al., 2018). Interestingly, scores on the Rapid Letter Naming subtest, along with the Digit Span Backwards subtest, were not shown to be statistically significantly associated with reading comprehension performance, although a moderate effect size was found between scores on the Elision and reading comprehension. Rapid Letter Naming scores and working memory scores (as measured by DSB) were significantly correlated, which is unsurprising, as the Rapid Letter Naming subtest draws on the participant's ability to efficiently retrieve phonological information from memory. Despite working memory being conceptualized as part of EF in current research models (Miyake et al., 2000), and attention thought to be a component of working memory (Baddeley, 2003), DSB scores had only a small association with teacher ratings of ADHD and EF in this study. A lack of statistically significant findings between these measures may be the result of the measurement tool used to capture working memory or the subjective nature of the rating scale. The ADHD and EF rating scales utilized in this study were secondary measures of assessment (behaviour rating scales), while the Digit Span Backwards subtest was a primary measure testing working memory capacity. In addition, EF rating scales draw on cognitive capacities beyond just working memory (eg. attention, shifting, planning,

organization), likely minimizing this association. In addition, there are a variety of measures used to tap working memory, and although research suggests that these measures are highly correlated, it is generally recommended that researchers draw on a heterogenous set of assessments when measuring this construct (Wilhelm et al., 2013). For example, the DSB subtest draws on one's ability to verbally manipulate digits in working memory, rather than the manipulation of semantic information. Studies examining the association between working memory and reading comprehension often use a combination of measures that draw on both manipulation of digits, as well as semantic information (Christopher et al., 2012; Swanson & Jerman, 2007).

A moderate association between teacher ratings of EF and reading comprehension performance was identified in this study. Support for the association between these constructs is reflected in the literature (Cartwright et al., 2017; Follmer, 2018; Meixner et al., 2019). Teacher ratings of EF were also significantly correlated with both word-level reading measures, reflecting similar findings in other research (Haft et al., 2019; Jiang et al., 2018; Nouwens et al., 2021). Contrary to what was predicted in this study and findings from other research (Christopher et al., 2012), Teacher rated EF scores were not related to either language comprehension measure. In a study of 271 English-speaking children, Spencer and colleagues (2020) found that the association between EF and language comprehension was stronger than that of EF and decoding, and that this pathway partially mediated the relation between reading comprehension and EF (Spencer et al., 2020). As stated before, a lack of findings reported in this study may be the result of the small sample size or because of the challenges posed by administering assessments remotely, which is discussed in more depth later in this paper. Nevertheless, this association

further supports current research providing evidence for the theory that EF draws on capacities that are important for academic success (Jurado & Rosselli, 2007; Singer & Bashir, 1999).

Strong evidence linking attention to academic achievement and reading comprehension has been reported in the research (Cain & Bignell, 2014; Giannopulu, 2008; Rabiner et al., 2000), and findings from this study give some evidence to corroborate this association. Teacher ratings of ADHD were moderately correlated with reading comprehension, suggesting that higher rates of ADHD symptoms are associated with weaker reading comprehension performance. Findings did not reach statistical significance, likely do to the power of the study. In addition, research investigating the association between attention and reading comprehension is often conducted on a clinical participant sample (e.g., Cohen et al., 2000; Frazier et al., 2007), and the use of both parent and teacher ADHD ratings scales are often utilized (e.g., Helland et al., 2016). Difference in sample composition and measurement may have also influenced findings. For example, in a meta-analysis conducted by Frazier and colleagues (2007), the authors found that the effect sizes associated with ADHD and academic achievement was greater in large sample sizes. As this study used a small sample size, this may have weakened the correlation between teacher ratings of ADHD, reading comprehension performance, and it's underlying components.

Higher teacher ratings of ADHD symptoms were moderately associated with weaker word reading scores, and a small effect size was found between higher teacher ratings of ADHD symptomology and weaker pseudoword reading ability. A similar association between attention and word level reading skills is reported in the literature (Costa et al., 2013; Martinussen et al., 2014; Plourde et al., 2018). Inattentive symptoms may interfere with aspects of learning, such as focusing on instruction and information, which may negatively affect the development of

phonological awareness, leading to difficulties in decoding and reading comprehension (Plourde et al., 2018). Of the six participants whose ADHD symptoms were above average, only two had below average scores on reading comprehension performance. These two participants showed greater difficulty in word-level reading skills, supporting the theory that decoding is an important component of reading and understanding text (Haft et al., 2019; Hagtvet, 2003; Slot et al., 2016), reflecting the SVR. Some research has also found a link between poor phonological processing and attention problems (Costa et al., 2013; Martinussen et al., 2014; Plourde et al., 2018; Sims & Lonigan, 2013), and findings from this present study add support for this association. Higher teacher ratings of ADHD symptoms had a small association with weaker phonological awareness as measured by Pseudoword Decoding and the Elision subtests. Similar results have been reported in other research with participants of a similar age (Miller et al., 2014). Teacher ratings of ADHD symptoms did not significantly correlate with either language comprehension measure, contrary to other research reporting a link between attention and language comprehension (Cain & Bignell, 2014; Plourde et al., 2018). A lack of findings may be due to language comprehension tasks not adequately measuring this construct, or because only one ADHD rating scale was used, resulting in a less accurate representation of both ADHD symptoms and language comprehension ability. The findings of this study suggest that teacher ratings of ADHD symptoms may have a greater impact on word-level reading skills, rather than language comprehension skills.

A highly significant, positive correlation was also identified in this study between teacher ratings of EF and ADHD symptoms. This indicates that high rates of ADHD symptoms are associated with weaker EF skills. EF weaknesses have also been found to correlate with poorer attention in other studies (Vuontela et al., 2013), and individuals with ADHD often have EF

deficits (Castagna et al., 2019; Pennignton, 2005). The findings of this study add further support to the theory that attention and EF are drawing on similar capacities.

In summary, findings of the present study provide additional support for SVR as an effective framework for conceptualizing reading comprehension. Similar to other research, a strong association between word-level reading skills and reading comprehension was found (Haft et al., 2019; Hagtvet, 2003; Slot et al., 2016; Vellutino et al., 2004). An association between language comprehension and reading comprehension was also discovered, reflecting other research (Babayigit; 2015; Babayiğit & Shapiro, 2019; Kendeou et al., 2009; Lervåg et al., 2018). Higher rates of ADHD symptoms measured by teachers were also strongly positively correlated with weaker EF skills in this study, replicating findings of other studies reporting a strong association between these constructs (Castagna et al., 2019).

Predictors of Reading Comprehension

A hierarchical regression analysis was run to identify whether teacher ratings of ADHD symptoms predicted reading comprehension performance after controlling for word-level reading and language comprehension skills. Word reading composite scores and language comprehension composite scores explained 59% and 6.8% of the variance in reading comprehension performance, respectively. Word-level reading skills significantly predicted reading comprehension ability, reflecting similar research (Chiu, 2018; Cutting & Scarborough, 2006; Foorman et al., 2020). Language comprehension composite scores did not add statistically significant variance to the model, contradictory to current research reporting language comprehension to be a strong predictor of reading comprehension (Babayigit; 2015; Babayiğit & Shapiro, 2019; Kendeou et al., 2009; Lervåg et al., 2018). Although the language comprehension composite score did not add statistically significant variance likely do to the power of the study,

a similar amount of unique variance was reported in research examining reading comprehension performance after controlling for word-level reading skills. Cutting & Scarborough (2006) found that language comprehension added an additional 9% - 15% of the variance in reading comprehension performance after controlling for word level reading skills, depending on the reading comprehension measure used. In addition, the amount of variance explained by language comprehension may be influenced by the age of the participants, as some research suggests that decoding is a stronger predictor of reading comprehension performance in younger students (García & Cain, 2014; Foorman et al., 2020). Nevertheless, a larger sample size, along with selecting a broader range of language comprehension subtests, may have produced statistically significant results. Although other studies have captured language comprehension ability by assessing vocabulary and syntactic knowledge when examining the association of language and reading comprehension (e.g. Foorman et al., 2020; Nouwens et al., 2021), it is also common for studies measuring oral language to use tasks assessing grammatical skills and listening comprehension, in addition to syntactic understanding and receptive language (e.g. Babayiğit & Shapiro, 2019; LARRC, 2017; Lervåget al., 2018; Nation et al., 2004).

After controlling for word reading and language comprehension scores, teacher ratings of ADHD added a further 1.9% of the variance to reading comprehension performance, but was not statistically significant. Cutting & Scarborough (2006) also reported that measures of attention only minimally improved prediction of reading comprehension scores. Some research investigating these constructs has found that the association between attention and reading comprehension is through an indirect pathway by its influence on word reading and language comprehension (Cain & Bignell, 2014; Jiang et al., 2018). As few studies have controlled for word-level reading and language comprehension skills in order to discover if ADHD

symptomology adds unique variance in predicting reading comprehension performance, it makes it difficult to compare findings from this study to other research. This gap in the literature may be due to the challenges associated with measuring and conceptualizing the construct of attention (Fletcher, 1998). Further research is needed to better understand the role that attention plays in predicting reading comprehension.

A second hierarchical regression analysis was run to discover whether teacher rated EF skills predicted reading comprehension ability beyond word reading and language comprehension skills. Similar to the previous analysis, word reading composite scores explained explained 49% of the variance in reading comprehension scores and language comprehension composite scores explained 6.8% of the variance. As above, word reading skills were a significant predictor in reading comprehension performance, reflecting similar findings in children at this stage of development (Garcia & Cain, 2014). Teacher rated EF scores contributed 3.9% of the variance in reading comprehension ability after controlling for word level reading and language comprehension ability, but was not found to be statistically significant in this study. A similar finding was reported by Sesma and colleagues (2009). The authors controlled for attention, word reading skills, reading fluency, and vocabulary and found that working memory added an additional 4% to the variance in reading comprehension and planning added a further 4%. Nouwens et al. (2021) also found that working memory and planning added unique variance to reading comprehension after controlling for decoding and language comprehension skills. Thus, there is evidence to suggest that EF skills are important for successful comprehension of text, as readers are required to use “higher-order” cognitive skills to plan, manipulate information in their memory, and monitor understanding and reasoning (Nouwens et al., 2021). The ability to inhibit behaviour, selectively attend, hold information in one’s memory,

and think flexibly about that information are all components conceptualized as part of EF (Diamon, 2013), and appear to be necessary for successfully understanding text beyond just word-level reading skills and language comprehension. In contrast, some research has found that EF scores do not contribute significantly to reading comprehension after controlling for the basic components of reading comprehension outlined in the SVR (Haft et al., 2019), and that the relation between EF and reading comprehension is better explained through its association to oral language and decoding (Spencer, et al., 2020).

Likely explanations for the differences between the prior studies and the findings reported in this study include sample composition and size, and variation in reading comprehension measures across studies. For example, the amount of variance contributed to by language ability, word reading skills, and cognitive skills to reading comprehension scores has been found to vary substantially across reading comprehension measures (Cutting & Scarborough, 2006). In addition, the amount of unique variance that EF contributes to reading comprehension has been shown to differ across reading comprehension measures (Cutting et al., 2009), suggesting that reading comprehension tasks place differing demands on bottom-up skills like word decoding and higher level skills such as oral language and EF (Cutting et al., 2009). Future research examining the unique variance to reading comprehension predicted by EF may benefit from using more than one reading comprehension measure.

In addition, studies controlling for components of reading comprehension reflected in the SVR in order to identify the variance that EF has in predicting reading comprehension performance tend to use older participants compared to the present study's sample (e.g. Cutting, et al., 2009; Nouwens et al., 2021; Semsa et al., 2009). Potentially, because EF ability increases with age (Zelazo, 2004), the amount of variance in reading comprehension explained by EF may

be greater in older participants. Contrary to this perspective, a meta-analysis conducted by Follmer (2018), did not find that the correlation between EF and reading comprehension varied systematically by age. Longitudinal studies exploring the predictive value of EF to reading comprehension after controlling for language and word-level reading ability may illuminate the influence that EF has on reading comprehension across development.

Finally, given that there is inconsistent agreement across the literature regarding whether or not EF predicts reading comprehension after controlling for commonly accepted contributors to reading comprehension, it may be possible that EF contributes only a small percentage to reading comprehension beyond these skills. Given the present study's small sample size, there is limited statistical power to discover significance for the small contribution that EF may make to reading comprehension. It would be beneficial for future studies investigating the unique contribution of EF to reading comprehension performance to utilize larger sample sizes to allow for better detection of significant but small effect sizes.

Reading Profiles of Students at-risk for Executive Functioning Impairment

A notable trend in the reading and language profiles of the four participants who had high teacher-ratings of EF difficulties was that these participants all scored in the average or higher range for all language comprehension subtests, except for one participant's score on the Picture Vocabulary subtest. There are inconsistencies across the research with regard to the contributions that EF skills have in the development of language comprehension. Nouwens et al. (2021) found that in a sample of 113 fourth grade children, EF did not contribute to language comprehension skills. In contrast, a longitudinal study of 18,000 kindergarten to grade 1 students participated in a study by Chang (2020). The author found that the association between EF and reading comprehension was heavily mediated by language comprehension. Other research has found that

EF has an indirect effect on reading comprehension through its influence on language comprehension (Hung, 2020). It is suggested that EF is required for readers to evaluate and make sense of grammatical structures in language which is necessary for comprehending text (Hung, 2020). Further research examining the indirect and direct effects of EF to reading comprehension, and discovering the mediators that transmit EF effects to reading comprehension, would be a valuable extension of the current literature.

Of the four participants with high scores on the EF rating scale, three students scored at the low average range or lower on the Pseudoword Decoding subtest, and two of these students scored in the well below average range on the Word Reading subtest. Poor EF has also been linked to weaker word-level reading ability in other research (Haft et al., 2019; Jiang et al., 2018; Nouwens et al., 2021). Surprisingly, of the two students with difficulties in both word reading and decoding, only one had difficulties in reading comprehension. These findings give some support to the SVR, as the students with reading comprehension difficulties demonstrated challenges with psuedoword decoding, word reading, and vocabulary, although these profiles were inconsistent across the two children. A larger sample of participants demonstrating EF difficulties would be necessary to draw conclusions about the associations between components of reading comprehension presented in the SVR for children and EF deficits.

Contrary to this study's hypothesis, only two of the four participants with high teacher ratings of EF difficulties demonstrated reading comprehension challenges. Some research suggests that the capacity for mental manipulation and efficient planning (two components of EF) are an important component of comprehending written text beyond the basic underlying skills associated with reading comprehension (Semsa et al., 2009). This is understandable, as readers must hold information relating to text that has already been read in their short-term

memory, while continuing to extract meaning from sentences (Swanson, 1999). Nevertheless, this study suggests that even students with EF difficulties as identified by teachers can still develop word-level reading skills, language comprehension skills, and reading comprehension ability.

It is worth noting that one of the four participants scored below average on the DSB subtest (SS: 80) and well below average on the Reading Comprehension subtest. Some research has found that working memory has a direct effect on reading comprehension (Nouwens et al., 2021), and that individuals with reading disabilities experience problems across components of working memory (such as the articulatory loop and central executive) (Swanson, 1999). Students with working memory difficulties seem to be at a distinct disadvantage when it comes to comprehending text (Swanson & Jerman, 2009). It is clear from the literature that poor working memory skills act as a significant risk factor for poor academic achievement (Alloway et al., 2009), but the extent to which working memory or other EF components can predict performance of subskills relating to reading comprehension is still unclear.

The differences across the reading and language profiles of these four participants may be the result of the type of EF deficits experienced by each child. Since EF is made up of various components that seem to be distinct, although highly correlated (van der Sluis et al., 2007), difficulties in a specific domain may result in a deficit in a specific skill associated with reading comprehension (eg. phonological awareness). This may partially explain the variation across these reading profiles. Studies with large sample sizes would be required to draw any conclusions about how different difficulties in specific areas of EF relate to challenges in component skills related to reading comprehension.

It is interesting to note that of the seven students scoring below average on the Reading Comprehension subtest, only two participants were considered at-risk for EF difficulties set out by the BRIEF 2 manual (these students' reading profiles were described in the above section). This has theoretical implications, as it draws attention to the current lack of understanding regarding the associations between EF difficulties and reading comprehension deficits. It is worth noting that although separate cognitive processes seem to be involved in the development of EF deficits and reading difficulties, reading problems have been found to contribute to the early onset of behaviour difficulties (Bennet et al., 2003). Some research suggests that difficulties with reading put students at future risk for poor task engagement, self-control, and internalizing and externalizing behaviours, while poor task engagement act as a risk factor for future reading difficulties. To what extent teacher ratings of EF in students are actually measuring behaviours in response to reading difficulties is beyond the scope of this study, but it is an important factor to consider in future studies. While research consistently supports the SVR model (Aouad & Savage, 2009; Chiu, 2018; Colenbrander et al., 2016; García, & Cain, 2014; Hagtvet, 2003), how impairments in subskills identified in this framework develop, and to what extent attention and EF plays a role, is not well understood.

Additional Considerations on Language Comprehension and Executive Function

Receptive vocabulary and syntactic understanding measures have been used to capture oral language comprehension in studies of reading comprehension (Foorman et al., 2020; Nouwens et al., 2021); however, oral language comprehension is a multifaceted construct. To gain a broader understanding of the relations between oral language and reading comprehension, future studies should operationalize oral language comprehension by including tasks that measure multiple skills involved in language comprehension, such as syntactic and grammatical

knowledge, as well as inference making (Cutting & Scarborough, 2006). For example, a longitudinal study involving children in grade 2 and 3 conducted by Metsala et al. (2021) found that vocabulary, syntactic awareness, and morphological awareness each contributed unique variance to reading comprehension after controlling for word level reading skills, and that morphological awareness was the most robust predictor. In addition, a study by the Language and Reading Research Consortium (2017) which sought to further understand the dimensionality of oral language, assessed 1,869 children from preschool to third grade to discover whether oral language as measured by expressive and receptive vocabulary, grammar, and listening comprehension were separate constructs. While the two-factor model (oral language and listening comprehension) had a better fit than a one-factor model, the two constructs were highly correlated, suggesting that oral language and listening comprehension can be characterized, to some degree, as a single language construct. Nevertheless, although highly correlated, components of language comprehension seem to form distinct constructs, and may each uniquely contribute to reading comprehension performance. Future research investigating the variables measured in this study would benefit from the use of a larger variety of language comprehension assessments that tap different oral language skills.

In studies examining the associations between EF and reading comprehension, EF is usually measured through a selection of performance-based measures capturing working memory, planning, inhibition, and attention (e.g. Chripstopher et al., 2012; Cutting et al., 2009; Haft et al., 2019; Hung, 2021; Nouwens et al., 2009) rather than rating scales, although rating scales are also used in addition to performance-based EF tasks (e.g. Cutting et al., 2009; Sesma et al. 2009). The current study relied solely on the BRIEF 2 rating scale measure. Although performance-based measures of EF attempt to tap specific dimensions of EF, they may be

limited in their generalizability to the context of the everyday environment. A study conducted by Toplak et al. (2013) looked at the association between rating scales and performance-based measures of EF in 20 studies. The authors found that the two different types of measures were only minimally correlated, and seemed to capture different mental constructs. The authors concluded that performance-based measurements and rating scales of EF draw on different aspects of cognition and behavioural functioning, which has implications for research. The authors state that performance-based measures do not adequately capture the influence of the environmental context, in which behaviour is driven by rational goal achievement (Toplak et al., 2013). Other studies have also found that rating scales and neuropsychological testing in EF assessment appear to capture different constructs (Barkley & Murphy, 2011; Biederman et al., 2008). While performance-based measures and rating scales of EF provide important information about cognition, the former seems to capture processing efficiency of an individual's cognitive abilities, while the latter seems to assess the extent to which an individual can regulate their behaviour to achieve goals (Toplak et al., 2013). In sum, the way in which EF is measured, either through performance-based tasks or through rating scales, has implications for research. Since these two types of measures may be capturing different cognitive capacities, they may uniquely influence the amount of variance that EF has in predicting reading comprehension performance. It would be beneficial for future research to use both performance-based measures and rating scales of EF when examining its relation to reading comprehension.

Implications of the Present Study

Reading comprehension is a necessary component of academic achievement (NRP, 2000), and evidence suggests that reading deficits tend to persist over a student's education (Francis et al., 1996; Kiuru et al., 2013; Vellutino et al., 2004). Early identification and

intervention is therefore crucial for students with reading comprehension difficulties. The present study supports the SVR model as an effective framework for conceptualizing reading comprehension. Findings from the study add to the body of literature which inform reading comprehension interventions, as it replicates findings on the influence of both word-level reading and language comprehension skills required for reading comprehension performance in school-aged children. Findings of this study heavily implicate the importance of word-level reading skills to reading comprehension performance in the elementary school years, reflecting other research (Garcia & Cain, 2014).

This study also contributes to the limited body of research examining the specific amount of variance that teacher ratings of ADHD and EF add to reading comprehension performance after controlling for commonly accepted skills underlying reading comprehension. While neither variable was found to significantly explain variance in reading comprehension performance beyond word-level reading skills and language comprehension, EF did approach statistical significance.

The Pseudoword Decoding measure was the only reading or language measure to significantly correlate with teacher ratings of ADHD, in contrast to the teacher ratings of EF, which was significantly correlated with word-level reading measures and reading comprehension performance. This finding suggests that teacher rated EF difficulties have a stronger association with word-level reading skills and reading comprehension compared to teacher rated ADHD symptoms. Perhaps this stronger association is because teacher rating scales of EF measure not only just the attentional focus and behavioural control that is captured in teacher ratings of ADHD, but also a broader collection of observable behaviours that subsume the EF umbrella, of which ADHD symptoms are partially a component. This finding reflects current frameworks for

conceptualizing EF, as the ability to selectively attend and ignore irrelevant stimuli, along with behavioural inhibition (as measured by the ADHD rating scale), is a component of EF often reflected in the literature (Diamond, 2013; Miyake et al., 2000). However, because of the small sample size and limited number of EF and attentional measures used in this study, similar findings would have to be replicated for any conclusions to be drawn.

This study adds new information to the literature examining the association between EF and reading comprehension, as studies examining these two constructs tend to draw on performance-based measures of EF (e.g. Chripstopher et al., 2012; Cutting et al., 2009; Haft et al., 2019; Hung, 2021; Nouwens et al., 2009). This study is the first to use the BRIEF-2 rating scale to examine the unique variance EF has in predicting reading comprehension after controlling for word-level reading and language skills. It would be worthwhile for future studies with larger sample sizes to use EF rating scales to predict reading comprehension after controlling for skills presented in the SVR model. The findings of the present study may also inform future research seeking to investigate the association of EF and attention to reading comprehension. It would be beneficial for subsequent studies to compare and contrast the contributions that performance-based or rating scale measures of EF have to reading comprehension performance. This is necessary to gain clarity on the different components of EF and attention that these measurement tools are capturing, and how these underlying constructs may influence reading comprehension in unique ways. In addition, it is still unclear whether the relation between EF or attention to reading comprehension is better explained by an indirect pathway through its influence on word reading and language comprehension ability, or directly. It would be worthwhile for research to examine the associations between these constructs with

larger sample sizes using structural equation modeling to inform future reading intervention programming.

Strengths and Limitations of the Present Study

The present study investigated the associations between reading comprehension, its underlying components (word reading and language comprehension ability), and teacher ratings of ADHD and EF in elementary school-aged children. This study sought to fill a gap in the literature as few studies have examined the unique variance that teacher ratings of EF or ADHD add to reading comprehension performance after controlling for word-level reading and language comprehension skills. Much research has found a link between reading comprehension and EF (Cartwright et al., 2017; Follmer, 2018; Meixner et al., 2019), but less is known about the causes of this pattern of comorbidity. By controlling for word reading and language comprehension skills, this study adds to the current information on the associations across these constructs. In addition, this study relied on norm-referenced measurements for each variable that have high reliability and validity and are commonly used in the educational psychology literature.

This study also had limitations. A cross-sectional research methodology was used, limiting understanding of how these constructs interact across a child's development. In addition, the statistical power to detect significance for small effect sizes was limited given the small sample size of the study. Furthermore, this study drew on a heterogenous participant sample, rather than just children with weak attention, EF, or reading comprehension. Consequently, conclusions drawn in this study may not be generalizable to students with deficits in these areas. In addition, children showing obvious weaknesses in EF processes, attention, and reading comprehension may produce clearer associations between these constructs, which would better help to inform future reading intervention programming. This study was also conducted on a

predominantly white, middle-class population, and thus may not be generalizable to individuals from other demographics. In addition, limited information was gathered about the participants. Parental level of education and SES are likely to also influence reading comprehension, but were not controlled for in this study.

Administration of assessments were conducted via Zoom, an online communications platform. The validity and reliability of psychoeducational assessment tools may not be consistent across administration modalities, and factors such as participants' acceptance of this modality, along with technical complications, may impact the reliability and validity of standardized assessment measures administered remotely (Luxton et al., 2014). In addition, there are few studies investigating the validity of remote assessment, which is problematic as norms for standardized assessments have been developed based on data gathered from in-person testing administration (National Association of School Psychologists, 2017). Despite these concerns, government agencies, professional organizations, and testing publishers have recommended the use of tele-assessment, with caution (Krach et al., 2020). These suggestions may be based on some research which has found that remote and in-person administration of cognitive and achievement tests are equivalent (Wright, 2018), but more research is needed to draw conclusions across standardized assessment measures.

In order to maintain validity and reliability when conducting psychoeducational testing through remote assessment, it is important for the participant’s environmental conditions to be optimized for the assessment procedure (Luxton et al., 2014). While attempts were made to administer assessments to participants in a quiet, isolated room, this wasn’t always feasible for some families. Consequently, environmental distractors may have influenced performance on these measures for some of the participants. Despite evidence supporting the use of remote

assessment administration (Wright, 2018), it is possible that conducting the assessments over Zoom may have impacted the reliability and validity of the data.

Since participation was voluntary, students who enjoyed school and school-related activities may have been more likely to want to participate. This may have influenced the findings of this study, as participants may have held a more positive affect towards academic tasks such as the ones conducted in this study, along with a more positive view of themselves as learners, compared with the general population. In addition, the author solicited participation from students in her own classroom. Thus, those willing to participate in this study from the author's class may have been influenced by the relationship between the author and the participant, potentially impacting the sample.

In addition, the Syntactic Understanding subtest was not normed for students above eight years and 11 months old. Seven participants were above this age range, also potentially limiting the validity of this measure. The present study was initially designed to include only grade 2 students, but significant challenges relating to recruitment arose because this study was conducted during the COVID-19 pandemic. Consequently, halfway through the study, the age range had to be increased, and no Syntactic Understanding Subtest is available for the TOLD I:4 that could be used with older students. Finally, because this study was conducted during the COVID-19 pandemic, these additional stressors may have increased parent reluctance to assist their child to participate in this study, potentially influencing the participant sample. Conducting the assessments remotely also may have prevented parents and children who did not have access to a home computer from wanting to participate. Despite these limitations and challenges, the current study has given further support for the SVR as an effective model for conceptualizing reading comprehension. In addition, this study adds further evidence to support the

interconnection between EF and ADHD symptoms. Finally, this study further corroborates current literature reporting the association between EF ability and ADHD symptoms to word-level reading skills and reading comprehension.

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