THE CONTRIBUTIONS OF COGNITIVE ABILITIES TO THE RELATIONSHIP BETWEEN INATTENTION AND ACADEMIC ACHIEVEMENT

by

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ABSTRACT

The main objective of this study was to examine whether increased levels of inattentive and hyperactive behaviours were associated with lower scores on standardized tests of achievement in basic reading, spelling, and math skills, after accounting for certain known background risk factors and cognitive processes. Clinical assessment data from a rigorously diagnosed, stimulant medication naïve sample of 354 elementary school-aged children experiencing academic difficulties and behavioural symptoms of inattention and/or hyperactivity/impulsivity were analyzed. It was expected that higher scores of inattention, not hyperactivity/impulsivity, would be associated with lower scores in basic reading, spelling, and math skills, and that these associations would persist after accounting for known background risk factors and cognitive processing variables. Results indicated that, although higher levels of inattention were significantly associated with lower scores in basic reading, spelling, and math scores, these associations did not persist after accounting for cognitive processes. Important factors for school psychologists to consider when conducting assessments, providing recommendations, and determining interventions for students with academic difficulties and perceived parent- and/or teacher-rated inattention are discussed.

LIST OF ABBREVIATIONS

ADHD = Attention-Deficit/Hyperactivity Disorder

ASD = Autism Spectrum Disorder

CD = Conduct Disorder

CHC = Cattell-Horn-Carroll theory of intelligence

DSM = Diagnostic and Statistical Manual of Mental Disorders

FRI = Fluid Reasoning Index

FSIQ = Full-Scale Intelligence Quotient

GAD = Generalized Anxiety Disorder

Gc = Comprehension Knowledge (Cattell-Horn-Carroll theory broad ability)

Gf = Fluid Reasoning (Cattell-Horn-Carroll theory broad ability)

Gs = Processing Speed (Cattell-Horn-Carroll theory broad ability)

Gsm = Short-Term Memory (Cattell-Horn-Carroll theory broad ability)

Gv = Visual Processing (Cattell-Horn-Carroll theory broad ability)

H/I = Hyperactive/Hyperactivity

ID = Intellectual Disability

INA = Inattentive/Inattention

IQ = Intelligence Quotient

LBW = Low birthweight

LD = Learning Disability/ies

M = Mean

MDD = Major Depressive Disorder

MH Disorder = Mental Health Disorder

N = Sample size

OCD = Obsessive Compulsive Disorder

ODD = Oppositional Defiant Disorder

OSD = Obstructive Sleep Disorder

PICS = Parent Interview for Child Symptoms

PSI = Processing Speed Index

PTSD = Post-Traumatic Stress Disorder

SD = Standard Deviation

SES = Socioeconomic Status

STEM = Science, Technology, Engineering, and Mathematics

TD = Typically Developing

TTI = Teacher Telephone Interview

VCI = Verbal Comprehension Index

VMI = Visual-Motor Integration

VSI = Visual Spatial Index

WIAT = Weschler Individual Achievement Test

WISC = Wechsler Intelligence Scale for Children

WMI = Working Memory Index

CHAPTER 1. AN OVERVIEW OF ACADEMIC ACHIEVEMENT: IMPORTANCE, INDICATORS, AND PREDICTORS OF ACADEMIC UNDERACHIEVEMENT

Academic achievement can be defined as a cumulative process that involves learning new academic skills and improving existing skills (Entwisle & Alexander, 1990; Pungello et al., 1996). Decades of research has established prior academic achievement as an important predictor of future academic achievement (Casillas et al., 2012), as well as future educational, psychosocial, and functional outcomes across the lifespan (Lansford et al., 2016). The importance of academic achievement in multiple domains across the lifespan has led to a substantial amount of research investigating which factors increase the risk of poor academic achievement, and several demographic, cognitive, and behavioural risk factors have been identified. However, academic achievement is a complex, multidimensional structure that is thought to be affected by several factors across development (Arnold et al., 2020), and the relationship between academic achievement and known risk factors is not always clear. For example, students with attention difficulties, which is the focus of the research study that follows this review, have consistently been shown to experience difficulties with academic achievement (American Psychiatric Association [APA], 2013; Daley & Birchwood, 2010; Mulholland, 2017). However, other factors, such as demographic characteristics or cognitive abilities, are thought to influence this relationship (Polderman et al., 2010). The literature review that follows provides an overview of these relationships.

This literature review will first define academic underachievement and discuss its importance across the lifespan. A brief overview of three important indicators of academic achievement, specifically reading, spelling, and math, will then be provided and the importance of these indicators throughout schooling and into adulthood will be discussed. An overview of specific demographic, cognitive, and behavioural predictors of academic achievement will then be provided. Demographic predictors will focus on age, sex, low birthweight, socioeconomic status, and family structure. Cognitive predictors will focus on cognitive abilities including verbal comprehension, visual spatial ability, working memory, processing speed, and visual-motor integration. Lastly, behavioural predictors will include inattentive and hyperactive/impulsive behaviours. Of note, these factors do not represent the entirety of factors that have been associated with academic achievement.

Academic Underachievement

Academic underachievement can be broadly defined as a negative discrepancy between the level a student is achieving academically relative to the student's cognitive abilities (Preckel & Brunner, 2015) or normative age (Rogers et al., 2011). Although several definitions have been postulated, currently, there is no universally accepted definition of academic underachievement (Shapiro & Schor, 2020). The lack of a universally accepted definition can, in part, be attributed to the inconsistent definitions and the types of outcome measures, namely subjective versus objective measures, used across studies (Preckel, 2006). Objective measures consist of standardized tests of achievement, in which underachievement is defined by scores below a specific cut-off point, typically one or more standard deviations below the mean (Preckel, 2006). Conversely, subjective measures often include grades or Grade Point Averages (GPAs), teacher-rated performance or progress, or curriculum-based outcomes (Gray et al., 2017; Langberg et al., 2011). While this type of measurement is typically referred to as academic performance (Langberg et al., 2011), several studies refer to it as academic achievement (e.g., Hoffmann, 2018). Although research has established that academic achievement and academic performance are separate indices that measure separate outcomes (Loe & Feldman, 2007), these terms are often used interchangeably.

Subjective measures are often influenced by factors that are not directly related to academic skills, such as prior grades, behaviour, demographics, motivation, effort, engagement, progress/improvement, and persistence (Brookhart et al., 2016). Factors beyond test scores and academic skills have been shown to determine grades, particularly in elementary school-aged students (Brookhart, 1994; Brookhart et al., 2016). Nevertheless, academic performance is considered to have strong ecological validity (Langberg et al., 2011), and teacher-assigned grades are among the strongest predictors of high school graduation and post-secondary education (Atkinson & Geiser, 2009; Bowers, 2014; Cliffordson, 2008). Given that university acceptance is most often based on grades, the association between grades and post-secondary education is not surprising.

Objective measures of academic achievement directly quantify academic skills (e.g., reading, math) relative to a student's normative age, which are most accurately measured by standardized achievement test scores (Gray et al., 2017). Standardized tests of achievement are thought to minimize potential confounding factors such as teacher bias, and when administered individually, are thought to minimize the variance associated with student-related factors (e.g., attention, motivation, effort; Kaufmann et al., 2012). The most notable disadvantages of standardized tests of academic achievement are the time and resources required for their administration and their lack of sensitivity to short-term treatment effects (Shapiro, 2011). Additionally, although standardized test scores are thought to be comparable across studies (Kaufman et al., 2012; Watkins et al., 2007), cut-off points vary across studies and are often arbitrarily assigned (Dombrowski et al., 2004; Shaywitz et al., 1992). Similar to subjective measures, standardized tests of achievement are strong predictors of future academic success and educational attainment (Casillas et al., 2012; Kaufman et. al., 2012).

Despite inconsistencies in definitions and measurement methodologies, existing definitions converge in that students are considered to be underachieving academically when outcome scores are below what would be expected given their cognitive abilities (Preckel & Brunner, 2015)), or normative age (Rogers et al., 2011). Additionally, regardless of definitions and measurement methodologies, academic underachievement has been consistently associated with poor functional outcomes across the lifespan (Brookhart et al., 2016; Lansford et al., 2016).

The Importance of Academic Achievement across the Lifespan

Academic achievement has been a topic of interest for several decades and has been researched extensively by disciplines such as education, sociology, criminology, economics, health, and psychology. Given the wide range of short- and long-term adverse functional outcomes across the lifespan that have been consistently associated with impaired academic achievement, this cross-discipline interest is not surprising. In the short-term (i.e., throughout schooling), academic underachievement has been associated with truancy, suspension, expulsion (Hoffmann et al., 2013; van Lier et al., 2012), grade retention, academic failure, and school dropout (Tremblay et al., 1992; Wagner, 1995). Importantly, the link between early academic underachievement and continued academic difficulties throughout schooling has been well-established in the literature (Casillas et al., 2012). Students who are academically underachieving as early as Grade 1 are more likely to have poor reading and math scores in Grade 12, more likely be suspended and to require remedial education services, and less likely to graduate from high school (Darney et al., 2013). The increased likelihood of high school dropout is of particular importance, as failure to graduate from high school, and subsequent lower levels of educational attainment, have consistently been associated with a multitude of long-term persistent adverse psychosocial outcomes in adulthood (Lansford et al., 2016).

In the long-term, academic underachievement and failure to graduate from high school have been associated with employment problems, lower income, and dependence on government assistance (Lansford et al., 2016). Lower levels of education have also been associated with an increased likelihood of nicotine dependence, mental health problems, and suicide attempts (Maynard et al., 2015; Vaughn et al., 2014). Additionally, prevalence rates of chronic disease and early death are higher in adults with low levels of education (Vaughn et al., 2014). This association is thought to be influenced by the relationship between lower levels of education, health risk behaviours (e.g., smoking, being overweight, and sedentary lifestyle), and lower income (e.g., unsafe neighborhoods, unhealthy food, lack of high-quality health care; Cuttler, & Lleras-Muney, 2006; Lantz et al., 2010). Furthermore, adults who have not graduated from high school are at increased risk of substance abuse (Ford et al., 2020) and are more likely to be incarcerated. In the United States, 57% of inmates have not received a high school degree (Bureau of Justice Statistics, 2013), with some studies reporting rates as high as 75-80% (Bonczar, 2003; Pettit & Western, 2004; The Sentencing Project, 2004). In Canada, 74% of the prison population has not graduated from high school, with Grade 7 reported as the average education level of newly admitted offenders (Ungerleider & Burns, 2002, as cited in Hankivsky, 2008).

The associations between academic underachievement and adverse short- and long-term outcomes have been well-documented and undisputed in the literature. According to the literature, it appears that academic underachievement creates a cascading effect of conditions that increase the risk of decreased functioning throughout school and into adulthood. Academic underachievement as early as kindergarten increases the likelihood of experiencing negative consequences (e.g., grade retention, suspension, expulsion) and continued underachievement, which in turn could potentially result in high school dropout and subsequent adverse outcomes in adulthood. Despite decades of research, disentangling the relationships between predictors and outcomes of academic underachievement has proven difficult, and it continues to be a prominent research topic.

Indicators of Academic Achievement

This review will focus on objectively measured academic achievement. The following section provides a brief overview of three academic skills, specifically reading, spelling, and math, that are often measured through standardized tests of academic achievement (such as the Weschler Individual Achievement Test; WIAT; Wechsler, 2009) to assess academic achievement. The importance of these skills in overall academic functioning and their associations with functional outcomes across the lifespan are discussed.

Reading. Reading has been broadly defined as the process of extracting and constructing meaning from written symbols that represent speech (Snow, 2002; Xu et al., 2015). Although the ultimate goal of reading is to understand written text (i.e., reading comprehension), reading can be conceptualized as an overarching term that encompasses several complex, correlated yet separable, processes and skills, such as decoding and reading comprehension skills (Christopher et al., 2012). Decoding, which is considered a basic reading skill and an essential component in the development of vocabulary and reading comprehension skills (Perfetti, 1992; Samuels, 1994; Stanovich, 2000), refers to the ability to rapidly and accurately identify printed words by transforming printed letters, or groups of letters (letter strings), into sounds (Perfetti, 1985). The automatization of decoding skills is thought to free available cognitive resources and facilitate the acquisition of new vocabulary and new knowledge (National Reading Panel, 2000; Samuels & Flor, 1997; Spear-Swerling & Sternberg, 1994). Difficulty with decoding words is frequently considered a causal factor in reading comprehension problems, with an estimated 85-90% of children with comprehension difficulties also experiencing decoding difficulties (Stothard & Hulme, 1995; Yuill & Oakhill, 1991). Children with good decoding skills are more likely to engage in reading activities than children with decoding difficulties (Cunningham & Stanovich, 1991). Unsurprisingly, increased engagement in reading activities is associated with greater reading competence across development (Guthrie et al., 1999). Also unsurprisingly, decreased reading engagement in early grades has been shown to predict both a general overall aversion to future reading and a specific increased disengagement from reading books that are important to a student's education, such as history, science, and math text books (Grigg et al., 2003; Perie et al., 2005).

Reading is considered one of the most important academic skills a student can learn and a foundational skill necessary for learning school material across all subjects (Lesnick et al., 2010). The importance of reading is understandable given that students require grade-level reading skills in order to read grade-level textbooks and learn most school-related subjects. Consequently, students with reading difficulties will struggle to maintain good grades and to do well academically across most subjects. Early reading difficulties are persistent, with an estimated 75% of students experiencing reading difficulties in Grade 3 continuing to struggle to read in Grade 9 (Francis et al., 1996). Additionally, students with reading difficulties in Grade 3 are more likely to experience behavioural difficulties, social problems, grade retention, and are less likely to graduate from high school or attend university (Feister et al., 2010).

Reading difficulties have not only been associated with subsequent poor academic achievement throughout school (Willcutt et al., 2007b), but also with adverse functional outcomes in adulthood, such as psychosocial difficulties (Copeland et al., 2010; Richards et al., 2001), unskilled employment and lower occupational status (Dubow et al., 2006), and unemployment or income that falls below the poverty level (Kutner et al., 2007). Considering the importance of reading for learning throughout school, the associations between reading difficulties and future academic success, as well as the associations between reading and adult functional outcomes, it is unsurprising that reading is the most studied academic skill.

Spelling. Spelling has been defined as the process of converting oral language into graphically represented symbols based on a set of rules or conventions (Hodges, 1984), and has been conceptualized as a component skill of writing (Juel, 1988; Juel et al., 1986). According to the simple view of writing, writing consists of lower order skills, such as spelling and transcription, and higher order skills, such as generating, planning, and organizing ideas (Hayes & Flower, 1980; Juel, 1988; Juel et al., 1986; Scardamalia & Bereiter, 1986). Spelling skills have been shown to predict writing composition skills consistently from Grade 1 through to Grade 7 (Abbott et al., 2010). Research suggests that students with spelling difficulties may forget writing ideas initially generated because the task of spelling increases cognitive demands and limits the cognitive resources available to integrate and write ideas coherently (Graham, Berninger et al., 1997). Empirical studies have provided support for this theory, suggesting that poor spelling skills can impede an individual's available cognitive resources and create difficulties in efficiently generating writing ideas (Abbott & Berninger, 1993; Moats, 2006). Brain imaging studies have also provided support for increased arousal in brain regions thought to house the executive functions of working memory in children with spelling difficulties when they are attempting to spell words to compose written text (Richards et al., 2012).

Difficulties with spelling and writing composition have been shown to be strongly associated with impairments visual-motor integration skills (Berninger et al., 1992). Visual-motor integration skills are commonly referred to as a combination of hand-eye coordination skills and fine-motor control (Beery et al., 2010) and will be discussed in greater detail in the *Cognitive Abilities* section below. Briefly, difficulties with these skills are thought to increase cognitive demands necessary for the efficient acquisition of academic skills, such as spelling, writing, and reading (Berninger et al., 1992; Son & Meisels, 2006; Sulik et al., 2018). Spelling and reading skills are thought to develop synergistically and reciprocally (Ehri, 2000), but not in complete parallel (Abbott et al., 2010). For example, children with reading difficulties almost always have difficulties with spelling, and children without spelling difficulties typically do not have reading difficulties (Fayol et al., 2009). However, children without reading difficulties are typically able to read many more words than they can spell (Berninger et al., 2002) and sometimes continue to experience spelling difficulties (Foorman et al., 2010).

A student's ability to write (i.e., produce legible letters using correct spelling to create written texts) is of major importance throughout school across all subject areas, as a considerable amount of schoolwork consists of written assignments and tests (Abbott, 2010). As students progress through school to increasingly higher grades, the demands for written work increase. Students with spelling and writing difficulties are at increased risk of failing tests, receiving low grades (as a result of incomplete, unsubmitted, or low-quality assignments), and grade retention (Abbott et al., 2010; Jenkins et al., 2004). Spelling difficulties are stable, persisting into adolescents and adulthood, and have been associated with high levels of impairments in day-to-day literacy-related tasks that often result in adults opting for low-skilled occupations without literacy demands (Maughan et al., 2009). With business leaders currently identifying writing as a necessary skill in the workplace, adults with spelling and writing difficulties are more likely to experience difficulty finding employment (Aschliman, 2016; National Commission on Writing, 2004). Understandably, the ability to communicate ideas in writing is a necessary and critical skill not only in school, but also in the workplace and in everyday life situations (Aschliman, 2016; Capodieci et al, 2018).

Mathematics. Basic math skills consist of procedural and conceptual math skills (National Research Council, 2005). Procedural skills refer to the step-by-step processes applied to solve math tasks, whereas conceptual skills refer to a deep understanding of math facts, relationships, and patterns, and the ability to link newly learned concepts to previously learned concepts (Miller & Hudson, 2007). Procedural and conceptual skills are thought to develop interactively, with improvements in one skill leading to improvements in the other (Rittle-Johnson & Alibali, 1999; Rittle-Johnson et al., 2001). Additionally, math proficiency requires declarative math knowledge, defined as automaticity in retrieving math facts from memory (Miller & Hudson, 2007). Declarative math knowledge has been shown to facilitate skill retention and concept generalization, and to help students progress to more advanced mathematics (Ivarie, 1986; Miller & Heward, 1992). These skills are necessary for math calculations from simple single-digit addition in lower elementary grades, to advanced math problems in upper grades in high school.

Math skills are hierarchical and learned sequentially with each skill increasing in complexity and building upon previously learned skills (Fuchs et al., 2015; Koponen et al., 2016; Miller & Hudson, 2007). Unlike reading, where students “learn to read” by Grade 3 and are expected to “read to learn” from Grade 3 onwards (Chall, 1983), new and increasingly complex math skills and concepts are learned throughout all levels of school. Given the highly hierarchical nature of math skills, it is unsurprising that early math skills are critical for the acquisition and proficiency of subsequent math skills (Cowan et al., 2011; National Mathematics Advisory Panel, 2008). Difficulties with basic math facts, such as basic addition or subtraction facts, are thought to limit the cognitive resources available for more complex math tasks (Geary & Hoard, 2005). Research suggests that math skills are highly stable across grades (Aunola et al., 2004; Jordan et al., 2006), and mastering basic math skills, such as arithmetic, is essential to learning more complex math skills (Cowan et al., 2011; National Mathematics Advisory Panel, 2008).

Early math skills have been shown to predict not only later math skills, but also later achievement across all academic domains, overall educational attainment, and functional outcomes in adulthood (Duncan et al. 2007). Students with strong math skills are more likely to be involved in Science, Technology, Engineering, and Mathematics (STEM) programs and pursue a post-secondary education within these disciplines (National Council of Teachers of Mathematics, 2000). With STEM disciplines being among the fastest growing occupational clusters (Carnevale, 2014), and with math difficulties persisting into adulthood (Williams et al., 2003), adults with poor math skills are disadvantaged by fewer options occupationally (Ritchie & Bates, 2013). Math difficulties throughout school have also been shown to predict adverse functional outcomes in adulthood, such as low income, poor health, increased vulnerability for depression, and increased criminality (Parsons & Bynner, 2005). Additionally, math skills at 7-years old have been shown to be strong predictors of adult socioeconomic status at 42-years old (Ritchie & Bates, 2013). Despite the functional impairments that have been consistently associated with math difficulties throughout school and across the lifespan, research on math skills is a relatively new and emerging field that has been studied substantially less than reading skills.

Predictors of Academic Achievement

Empirical literature has consistently identified several demographic, cognitive, and behavioural factors that are associated with academic underachievement. The main focus of the research study that follows this review is the relationship between inattention and academic underachievement. The selection of variables in the study that follows was guided by previous research suggesting that demographic and cognitive factors should be taken into account in studies investigating the relationship between inattention and academic achievement to avoid potential confounding (Polderman, 2010). Therefore, this review will focus on factors that previous research has identified as important predictors to include in studies investigating this relationship. Notably, certain demographic variables (e.g., age, sex, socioeconomic status) are commonly included in research investigating this relationship. The factors included in this review do not represent the entirety of factors that have been shown to predict academic achievement.

The following section provides a brief overview of certain demographic factors (age, sex, low birthweight, socioeconomic status, and family structure), cognitive factors (verbal comprehension, visual spatial ability, working memory, processing speed, and visual-motor integration), and behavioural factors (inattention and hyperactivity/impulsivity). The individual contribution of these factors to academic underachievement has been well-established in the literature. However, these factors have not been studied together to determine their overall influence on academic achievement. Importantly, these risk factors not only tend to co-occur but have also been shown to influence each other. The section that follows will discuss the direct associations between each factor and academic achievement, as well as the relationships between these factors and other key variables.

Demographic Factors and Academic Underachievement

Age. Increasing age has been shown to differentially affect academic functioning across development and throughout schooling (DuPaul & Langberg, 2014; Polderman et al., 2010). Notably, factors such as motivation, peer relationships, social skills, school engagement, and study skills, have been shown to exert a greater effect on academic achievement in higher grades (Abikoff et al., 2013). Given that students suspected of academic underachievement are typically identified by their teachers, teacher perceptions of student progress are an essential component of the identification process (Jenkins & Kilpatrick-Demaray, 2015). However, teacher perceptions of student progress appear to vary as a function of student age. For example, teacher grading practices have been shown to vary by grade level, with lower elementary grade teachers using less formal evidence of learning compared to teachers of older students (Brookhart, 1994). Additionally, teachers are more tolerant of disruptive behaviours and more likely to rate behaviours as less disruptive for students in lower elementary grades than in later grades (Lundervolt et al., 2017). Teacher ratings of behaviour problems in higher elementary grades have been shown to be better predictors of future academic achievement than ratings from lower elementary grades (Lundervolt et al., 2017).

In terms of the associations between age, attention difficulties, and academic achievement, deficits in attentional skills are thought to influence academic functioning at a greater level with increasing age as academic demands increase with grade progression (DuPaul & Langberg, 2014). Similarly, planning and organization skills are also thought to affect academic functioning with increasing age, as older students are expected to assume greater responsibility for managing and organizing their homework, assignments, and school materials (Abikoff et al., 2013). Parents and teachers typically provide fewer prompts and reminders to children after Grade 3 or 4, which is thought to result in difficulties with planning and organizing becoming more evident at that age (Evans et al., 2005).

Given the relationships between age, inattention, and academic achievement at different developmental stages, it has been suggested that age could potentially confound results, and therefore, should be taken into account in studies investigating academic achievement and inattention (Lundervolt et al, 2017; Polderman et al., 2010; Salla et al., 2016).

Sex. Historically, research has identified differences between boys and girls in several areas of academic functioning. For example, studies suggest that boys receive higher scores than girls on tests of math achievement (Weaver-Hightower, 2003), whereas girls enter school with better developed literacy skills than boys (Ready et al., 2005) and score higher than boys in areas of literacy (Lesnick, et al., 2010; Ready et al., 2005; Reynolds et al., 2015). However, these differences in academic functioning between boys and girls tend to vary across developmental stages, and often depend on the specific skills being assessed (Reynolds et al., 2015). For example, although boys receive higher scores than girls on math concepts and problem-solving tasks, this difference tends to emerge in high school (Lindberg et al., 2010). Similarly, girls tend to score higher than boys on early basic math tasks, but this difference no longer exists in high school (Hyde et al., 1990). Similar trends have been shown in reading tasks. For example, girls score higher than boys on word decoding tasks, whereas boys score higher on nonsense word decoding tasks (Lachance & Mazzocco, 2006). Additionally, although girls enter school with higher reading skills, by Grade 8, the difference between boys and girls in reading skills is more pronounced in lower achieving students (Robinson & Lubienski, 2011). Although differences between boys and girls in reading and math appear to vary across developmental stage and tasks, girls have consistently been found to perform better than boys in all writing tasks (i.e., spelling, essay composition) across all developmental stages (Hedges & Nowell, 1995; Camarata & Woodcock, 2006; Reynolds et al., 2015).

Differences have also been found in certain cognitive abilities at the elementary school level, with girls receiving higher scores than boys on tasks measuring verbal abilities (Keith et al. 2011; Reynolds et al., 2008) and processing speed (Keith et al. 2011), and boys receiving higher scores than girls on visual processing tasks (Keith et al. 2011; Jirout & Newcombe 2015; Palejwala & Fine 2014). Although these differences tend to decrease with age, girls continue to score higher than boys on measures of processing speed across the lifespan (Keith et al. 2011). Notably, differences in verbal and visual processing abilities, although statistically significant, tend to be small and vary across measures (Scheiber et al., 2016).

Differences have also been noted between boys and girls in other areas that are thought to affect overall academic functioning. For example, research suggests that boys are more likely than girls to have classroom behaviour problems, which are thought to affect literacy skills (Ready et al., 2005). Additionally, compared to girls, boys are more likely to receive lower grades (Dauber et al., 1993; McCoy & Reynolds, 1999) and remedial education services (Oswald et al., 2003), experience grade retention (Meisels & Liaw, 1993; Ready et al., 2005), suspension and expulsion (Gregory et al., 2010), and less be likely to graduate from high school (Dauber et al., 1993; McCoy & Reynolds, 1999). Differences between boys and girls have also been found in the age, trajectory, and rate of brain maturation which are thought to explain the differences in behaviour and onset of puberty (Lenroot et al., 2007). Boys are also overrepresented in certain mental health disorders, such as Attention-Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorder (ASD), Oppositional Defiant Disorder (ODD), Conduct Disorder (CD), and Learning Disabilities (LD), which are known to affect academic achievement (APA, 2013). Notably, boys and girls diagnosed with mental health disorders tend to present with different symptoms. For example, boys diagnosed with ADHD are more often hyperactive and/or impulsive than girls with ADHD, and girls with ADHD are more often inattentive than hyperactive and/or impulsive (Günther et al., 2010).

Overall, research has identified differences between boys and girls in areas of academic skills, cognitive abilities, behaviour, school functioning, and mental health. Given the differences between boys in girls in a wide range of factors that could potentially influence academic achievement, researchers studying academic achievement have suggested that sex differences could be confounding factors and should be taken into account to avoid potential bias (Polderman et al., 2010).

Low Birthweight. Low birthweight (LBW) is defined as a weight of less than 2500 grams at birth and is typically associated with preterm birth, defined as a gestational age of less than 36 weeks (Taylor et al., 2019). Advancements in technology and improvements in neonatal intensive care have led to a decrease in the gestational age and birthweight at which infants are considered viable, and subsequently, an increase in the survival rates of children born preterm with LBW (Richardson et al., 1998; van Veen et al., 2018). Although this interruption in the natural developmental processes disrupts the development of all vital organs, the brain, the heart, and the lungs are more susceptible to vulnerabilities at this developmental stage than other organs (Goldenberg et al., 2007; Luu et al., 2016; Rees & Inder, 2005). Consequently, this disruption leads to a greater risk of neurological and health-related vulnerabilities across the lifespan (Van Baar et al., 2005; Saigal & Doyle, 2008). Children born preterm with LBW have been shown to be at an increased risk for developing chronic health problems, cognitive impairments, attention deficits, motor impediments, social emotional problems, and difficulties with academic functioning (Aarnoudse-Moens et al., 2011; Van Baar et al., 2005;; Doyle et al., 2014; Roberts et al., 2011).

Compared to their full-term peers, children born preterm with LBW experience higher rates of developmental delays and impairments that are known to hinder academic progress. For example, preschool children who were born with LBW have higher incidence rates of motor difficulties (Potharst et al., 2011), cognitive impairments (Arpi et al., 2019), and language delays (Barre et al., 2011), and consequently, often meet developmental milestones later than expected (Saigal & Doyle, 2008). Studies report an estimated 30% to 75% of LBW children continue to experience difficulties with motor, cognitive, and language skills at school entry (Aarnoudse-Moens et al., 2011, Arpi et al., 2019). Subsequently, they may enter formal schooling with poor school readiness skills (Shah et al., 2016), which is a known risk factor for continued academic underachievement (Duncan et al., 2007). During their early school years, LBW children often require speech therapy, occupational therapy, physical therapy, and/or remedial education services (van Veen et al., 2018). Although remedial interventions have been shown to improve functioning to varying degrees, these difficulties often persist throughout school and into adulthood (Aarnoudse-Moens et al., 2009; Mulder et al., 2009; Matthewson et al., 2017).

Throughout schooling, a large proportion of children born with LBW have been shown to experience a wide range of cognitive impairments. Compared to their full-term peers, children born with LBW obtain lower scores on tests of cognitive abilities (Hirschberger et al. 2018), with a substantial proportion scoring more than one standard deviation below their same-aged peers

(Hallin et al., 2010; Joseph et al., 2016). Cognitive impairments appear to be global, with deficits noted across all cognitive abilities (Hirschberger et al. 2018; Johnson et al., 2018; Joseph et al., 2016). Given the well-documented association between cognitive impairments and academic functioning (Deary et al., 2007; Kaufman et al., 2012; Lynn & Meisenberg, 2010; Rindermann, 2007), the academic difficulties experienced by this population is unsurprising. Academic underachievement in this population is evident when measured by standardized measures of academic achievement (Joseph et al, 2016; Saigal et al., 2008), as well as when measured by grades (Halin et al., 2010). Although several studies indicate more pronounced difficulties in math skills (Aarnoudse-Moens et al., 2009), difficulties have been noted across all academic domains and often persist into adolescence (Costa et al., 2017; Joseph et al., 2016; Johnson et al., 2011; Saigal et al., 2008). Consequently, high rates of LBW children require remedial academic services and experience grade retention (Pritchard et al., 2014), with rates increasing during middle childhood and adolescence (Saigal et al., 2008).

LBW children also experience high incidence rates of neurodevelopmental and other mental health disorders, which are known to affect academic achievement (Hirschberger et al., 2018). In fact, the prevalence of any psychiatric diagnosis across the lifespan is more than three times higher in preterm or LBW individuals compared to full-term and normal birthweight controls (Burnett et al., 2011). LBW has been associated with high rates of LD, ASD, Intellectual Disability (ID), anxiety and depressive disorders, cerebral palsy, and epilepsy (Burnett et al., 2011; Gardener et al., 2011; Hirschberger et al., 2018; Leavy et al., 2013). Of particular interest, LBW children are approximately three to six times more likely than their full-term peers to be diagnosed with ADHD (Franz et al., 2018). Interestingly, although ADHD is typically characterized by a male predominance in the general population, a recent metanalysis found a substantially higher prevalence of ADHD in females than in males born at LBW (Franz et al., 2018). Notably, severe attention problems are commonly present in LBW children, even when they do not meet diagnostic criteria for a diagnosis (Matthewson et al., 2017).

Socioeconomic Status (SES). SES can be conceptualized as an indicator of an individual's access to collectively desired resources, such as material goods, wealth, power, friendship networks, healthcare, leisure time, or educational opportunities (Oakes & Rossi 2003). Since SES is a latent variable and cannot be directly measured, contemporary measures typically quantify SES through univariate proxy measures such income, educational attainment, or occupation, or through composite measures that include a combination of these indicators (Conger et al., 2010; Oakes, nd). These indicators of SES are positively correlated (Ensminger & Fothergill, 2003) but demonstrate different levels of stability across time (Duncan & Magnuson, 2003). Although no indicator or composite measure is considered a perfect measure of SES, educational attainment is considered the most stable indicator of SES (Oakes, nd; Sirin, 2005) and has been found to be a strongest predictor of occupational status and income (Becker et al., 2019). Given its influence on subsequent occupation and income, education is thought to be the fundamental component of SES (Krieger et al., 1997; Mueller & Parcel, 1981), and is one of the most frequently used indicators of SES (Conger et al., 2010)

The SES of the family an individual is born into has been shown to be associated with a wide range of outcomes, including academic achievement (Caro, 2009). The association between low SES and academic underachievement has been well-established and undisputed in the literature for decades (Sirin, 2005; White, 1982). Research suggests that low SES backgrounds place students at a disadvantage through their limited access to resources that facilitate learning and academic success (Bradley & Corwyn, 2002). Compared to their higher SES peers, children from low SES families enter school with fewer academic skills (Washbrook & Waldfogel, 2011). Impairments in the development of early academic skills are thought to be a consequence of a lack of experiences prior to formal education that foster school readiness, such as preschool attendance or the quality of preschool, and an enriched home learning environment (Buckingham et al., 2014). Compared to children from higher SES families, children from low SES families demonstrate less proficient literacy skills at school entry (Henning et al., 2010; Washbrook & Waldfogel, 2011). Research suggests that children with early reading difficulties from low SES backgrounds are more likely to remain poor readers throughout school than children with reading difficulties from higher SES backgrounds (Feinstein & Bynner, 2004). This difference is unsurprising when considering that struggling students from high SES families have access to additional supports, such as tutors or reading remediation programs. Adolescents from low SES families are less likely to graduate from high school and more likely to have behavioural and emotional problems throughout school (Lansford et al., 2016). Overall, low family SES places children at increased risk for academic underachievement through multiple pathways and frequently co-occurring adversities, such as limited access to recreational and learning opportunities (Bradley et al. 2001), deprived home learning environments (Buckingham, 2014), and poor physical and mental health (Bradley & Corwyn, 2002; Braveman et al., 2010).

Family Structure. Family structure, which is often considered a proxy measure for family stress, has been conceptualized as a sociodemographic indicator of a child's living situation based on the number of caregiving adults residing in the household with the child (O'Malley et al., 2015). Contemporary measures typically quantify family structure as single-parent or two-parent families (Huang et al., 2017). Although it is acknowledged that this dichotomous measurement of family structure is unable to represent the complexity and diversity of modern families (e.g., two biological parents, step-parents, divorced single parents, never married single parents, same-sex married parents), research suggests that the number of caregiving adults in a household is a key component of family structure (Biblarz & Stacey, 2010). Measuring family structure based on single- or two-parent households is a relatively non-intrusive indicator to obtain and has been shown to be a strong indicator of several important child outcomes, including academic achievement (Huang et al., 2017).

Decades of research have demonstrated that children raised in two-parent families fare better in school and across the lifespan than children from one-parent families (McLanahan & Garfinkel, 2000; McLanahan & Sandefur, 1994; Painter & Levine, 2000; Reardon, 2011). Compared to children from two-parent households, children living in single-parent families tend receive lower grades across all academic domains (e.g., reading, math, science, social studies), lower scores on standardized tests of academic achievement (Cataldi & KewalRamani, 2009; Jeynes, 2005; Sigle-Rushton & McLanahan, 2004), as well as lower scores on standardized tests of cognitive functioning (Carlson & Corcoran, 2001). Children from single-parent families are also more likely to experience grade retention (Hughes & Waite, 2002), and less likely to complete high school and pursue a post-secondary education (Cataldi & KewalRamani, 2009; Sigle-Rushton & McLanahan, 2004) than their peers from two-parent families. Additionally, children from single-parent families experience higher rates of long-term behaviour and health problems (Hill et al., 2001; Jeynes, 2005). Overall, family structure affects several aspects of functioning across the lifespan.

Family structure is theorized to exert its effects on academic achievement indirectly, through limited access to financial, parental, and social resources that are often consequences of single parenthood (McLanahan & Sandefur, 1994). In terms of financial resources, research has demonstrated a strong association between family structure and SES, with single-parent families often having lower incomes and being more likely to be living in poverty than cohabiting parents (Carlson & Corcoran, 2001; Huang et al., 2017; Jeynes, 2005). SES, as previously mentioned, is a strong predictor of academic achievement (Sirin, 2005). In terms of parental resources, single parents often have less time than cohabiting parents to dedicate to their children's education due to the multiple demands single parents face as sole providers and caregivers (Jeynes et al., 2005). On average, children from single-parent families receive less parental support (e.g., attention, guidance, monitoring, and encouragement) in school-related tasks, such as reading or homework assistance (Astone & McLanahan, 1991). Parental time restrictions are thought to lead to decreased parental involvement in daily school activities which in turn has been shown to negatively affect school outcomes (Park et al., 2011). Lastly, in terms of limited access to social resources, single parents often experience difficulties finding time to invest in personal relationships (e.g., scheduling playdates) and school-related activities (e.g., parent-teacher associations, volunteering for school functions; McLanahan & Sandefur, 1994). A child's limited participation in school events and limited access to meaningful relationships have been shown to negatively affect a child's educational outcomes (Park et al, 2011).

In Canada, the number of single-parent families has increased from 289,000 in 1976 to 698,000 in 2014 (Statistics Canada, 2015). Furthermore, the proportion of single-parent families in Canada was estimated to be 22% in 2011, compared to 6% in 1961 (Statistics Canada, 2014). Given the increasing trend of children being raised in single-parent households, as well as the well-documented association between family structure and academic achievement, family structure could be a potential confounding factor in studies investigation academic achievement.

Cognitive Abilities and Academic Underachievement

Cognitive ability, also referred to as intelligence, can be broadly defined as the ability to think abstractly, reason, problem-solve, and learn (Neisser et al., 1996; Snyderman & Rothman, 1987; Sternberg & Detterman, 1986). Given the definition of cognitive ability, it is unsurprising that cognitive ability would be strongly associated with academic achievement. However, considerable debate has historically surrounded the field of intelligence in general (Jung & Haier, 2007), and the association between overall cognitive ability and academic achievement more specifically (Ceci, 1991; Flanagan et al., 1997; Lubinski & Dawis, 1992; Watkins et al., 2007). Despite the controversy in the field, however, empirical evidence provides substantial support for the association between cognitive ability and academic achievement (Deary et a., 2007; Kaufman et al., 2012; Lynn & Meisenberg, 2010; Rindermann, 2007).

Empirical research has shown that psychometrically measured cognitive ability, commonly referred to as Intelligence Quotient (IQ), is highly correlated with standardized tests of academic achievement, with correlation coefficients ranging from the mid- .60s to as high as the mid- .80s (Naglieri & Bornstein, 2003; Weschler, 2003). The strong association between cognitive ability and standardized measures of academic achievement has been found to exist across different test batteries (Kaufman et al., 2012) and continues to persist after accounting for other factors known to influence academic achievement (Fergusson et al., 2005). Cognitive ability has also been shown to predict school grades (Gustafsson & Balke, 1993), with moderate to high correlations ranging from .40 to .70 (Mackintosh, 1998). The relationship between cognitive ability and school grades tends to be lower than the relationship between cognitive ability and standardized measures of academic achievement, which is unsurprising when considering the range of factors that are often included in determining grades (e.g., behaviour, motivation, prior grades; Brookhart et al., 2016; Kaufman et al., 2012). Besides academic achievement, psychometrically measured cognitive abilities have also been shown to predict a wide range of outcomes across the lifespan, such as level of educational attainment, income, occupational status, job performance, social abilities, and health-related behaviours (Almlund et al., 2011; Hanushek & Woessmann, 2008; Heckman & Vytlacil, 2001; Schmidt & Hunter, 2004; Strenze, 2007).

Contemporary theoretical models of intelligence view intelligence as a hierarchical structure, with overall intelligence consisting of distinct but correlated underlying cognitive processes or functions, which are thought to contribute to overall cognitive ability (Caemmerer et al., 2018; Reynolds & Keith, 2017). Although several theoretical models of intelligence have been proposed, currently the most influential model is the Cattell-Horn-Carroll (CHC) theory of intelligence (Reynolds et al, 2017; Schneider & McGrew 2012). The CHC theory views intelligence as a hierarchical structure, with general intelligence at the highest level, followed by broad cognitive abilities at the level below, and narrow cognitive abilities at the lowest level (Carroll, 1993; Horn & Blankson, 2005). Currently, most contemporary tests of cognitive abilities are, to a certain extent, based on this theoretical model (Kaufman et al. 2009; Newton & McGrew 2010; Scheiber, 2016), in which cognitive abilities are psychometrically measured to determine overall cognitive ability (McCall, 1977; Colom et al., 2002). For example, the conceptual foundation of the Wechsler Intelligence Scale for Children – Fifth Edition (WISC-V; Wechsler, 2014), which is the most recent edition of this measure and the most widely used assessment instrument for children worldwide (Scheiber, 2016), appears closely aligned with the CHC theory (Caemmerer et al., 2018; Reynolds et al., 2017; Scheiber, 2016). According to its creators, the development of the WISC-V was guided by the CHC theory and other contemporary theories, as well as neurodevelopmental research and clinical utility, but no specific theory determined its structure (Weschler, 2014). Although the creators of the WISC do not explicitly endorse a specific theory (Wechsler, 2014), several researchers have highlighted the similarities with the CHC theory (e.g., Reynolds et al., 2017, Scheiber, 2016).

The hierarchical structure of the most recent edition of the WISC assesses specific cognitive skills that collectively provide a measure of broad cognitive abilities (i.e., Primary Index Scores), and broad cognitive abilities collectively provide a measure of overall cognitive ability, referred to as Full-Scale Intelligence Quotient (FSIQ; Weschler, 2014). This hierarchical structure is consistent with its previous versions, but it differs in the number of specific skills (i.e., subtests) included in the measure of overall cognitive abilities or FSIQ (Weschler, 2014). The five primary indices on the WISC-V are the Verbal Comprehension Index (VCI), the Visual Spatial Index (VSI), the Fluid Reasoning Index (FRI), the Working Memory Index (WMI), and the Processing Speed Index (PSI; Weschler, 2014). These indices measure the cognitive abilities most contemporary structural models consider important components of overall cognitive ability, and according to its developers, are considered comparable to the CHC taxonomy constructs of Comprehension Knowledge (Gc), Visual Processing (Gv), Fluid Reasoning (Gf), Short-Term Memory (Gsm), and Processing Speed (Gs) respectively (Weschler, 2014).

Overall, cognitive ability is considered one of the strongest predictors of achievement across all academic domains (Deary et al., 2007; Kaufman et al., 2012; Kuncel et al., 2001). However, the effect of overall cognitive ability is thought to be mediated by specific broad abilities, which have been shown to have differential effects on specific academic domains (Caemmerer et al., 2018; Floyd et al., 2012; Hajovsky et al., 2014; Niileksela et al., 2016). Empirical studies have used psychometrically measured broad cognitive abilities (i.e., index scores from tests of cognitive abilities) to understand the relationships between specific cognitive abilities and specific academic domains. The following section will provide an overview of specific cognitive abilities that research has shown to be associated with different areas of academic achievement. These cognitive abilities will be discussed within the context of the WISC, as the study that follows this review includes scores from WISC indices, and the WISC is the most commonly used assessment instrument for children worldwide (Kaufman et al., 2016; Scheiber, 2016). Additionally, a measure of visual-motor integration, which is a cognitive ability that is not a component of the WISC, will be discussed. The relationships between these cognitive abilities and specific academic domains are discussed.

Verbal-Comprehension Index (VCI). The VCI is thought to be aligned with the CHC broad ability Gc (Caemmerer et al., 2018; Reynolds et al., 2017; Weschler, 2014). The VCI measures the ability to retrieve and express acquired verbal knowledge, which involves verbal reasoning (i.e., the ability to think about previously learned verbal information), forming meaningful concepts verbally, and expressing that knowledge. This cognitive ability is thought to be influenced by several underlying skills, such as the ability to acquire word knowledge, the ability to effectively retrieve and communicate that information, general reasoning, and problem-solving abilities (Weschler, 2014).

Empirical literature has consistently identified this cognitive ability as one of the strongest predictors of decoding, fluency, and reading comprehension skills (Benson, 2007; Caemmerer et al., 2018; Evans et al., 2002; Floyd et al., 2012; Glutting et al., 2006; Keith, 1999; McGrew et al., 1997; Niileksela et al., 2016; Oh et al., 2004; Vanderwood et al., 2002). Studies have also found moderate to strong associations between this ability and spelling skills (Caemerer, 2018; Cormier et al., 2016; Floyd et al., 2008) and have found this association to persist across the lifespan (Niileksela et al., 2016). Additionally, associations have been found with basic math and math problem solving skills (Floyd et al., 2003; Keith, 1999; McGrew & Hessler, 1995; Niileksela et al., 2016; Taub et al., 2008), although the associations with math skills have been found to be weaker for younger ages (Niileksela et al., 2016).

Visual Spatial Index (VSI). The VSI is thought to be aligned with the CHC broad ability Gv (Caemmerer et al., 2018; Reynolds et al., 2017; Weschler, 2014). The VSI measures the ability to perceive visual information, and to analyze, understand, integrate, and synthesize visual spatial relationships and patterns to generate geometric pattern from a model. This skill requires attention to visual details, visual-spatial reasoning (i.e., mentally manipulating or transforming visual information), and visual-motor integration (Weschler, 2014).

Difficulties with visual spatial abilities have been found to be associated with reading fluency in children younger than 13-years old, which is thought to be related to less automatized reading skills at younger ages (Berninger et al., 2006; Caemmerer et al., 2018). Visual spatial ability has been identified as a cognitive ability that is uniquely important for general math skills after accounting for overall cognitive ability (Lubinski et al., 2001). Specifically, visual spatial abilities have been associated with most areas of math, such as geometry (Battista, 1990; Delgado & Prieto, 2004), mental arithmetic (Kyttälä & Lehto, 2008), basic math skills (Thompson et al., 2013), algebra (Tolar et al., 2009), word problems (Hegarty & Kozhevnikov, 1999), and some areas of advanced mathematics (Sorby et al., 2013; Wei et al., 2012). Although associations have been found between visual spatial abilities and other areas of academic achievement, these results have been inconsistent (McGrew & Wendling, 2010).

Working Memory Index (WMI). The WMI is thought to be aligned with the CHC broad ability Gsm (Caemmerer et al., 2018; Reynolds et al., 2017; Weschler, 2014). The WMI measures the ability to attend to and perceive verbal and visual information, and temporarily retain the information in immediate awareness (i.e., maintenance) in order to process and manipulate (i.e., mentally re-sequence) the information (Weschler, 2014). Given its definition, it is evident that working memory skills are associated with every aspect of cognitive functioning and academic achievement (Bhandari & Badre, 2016). Working memory is thought to be a cognitive ability that exerts effects on academic achievement indirectly by affecting more complex higher order cognitive abilities, such as reasoning and abstract thinking (Luo et al., 2003; Rindermann & Neubauer, 2004; Vock et al., 2011).

Deficits in working memory have been associated with poor academic achievement across all academic domains (Alloway & Alloway, 2010). More specifically, working memory has been associated with decoding skills (Beaujean et al., 2014; Benson, 2007; Cormier et al., 2017; Evans et al., 2002; Hajovsky et al., 2014) and reading comprehension (Evans et al., 2002; Floyd et al., 2012), and is thought to be particularly important for early reading development (Caemmerer et al., 2018; Hajovsky et al., 2014). Working memory has also been found to predict spelling skills throughout schooling (Cormier et al., 2016; Floyd et al., 2008; Niileksela et al., 2016) as well as the ability to compose sentence and essays (Caemmerer et al., 2018). Additionally, studies have found that working memory is a strong predictor of a wide range of math skills (Gathercole et al., 2005; Mazzocco & Kover, 2007; Toll et al., 2011), with this association persisting across time and after controlling for overall cognitive ability (Alloway & Alloway, 2010).

Processing Speed Index (PSI). The PSI is thought to be aligned with the CHC broad ability Gs (Caemmerer et al., 2018; Reynolds et al., 2017; Weschler, 2014). The PSI measures the efficiency (i.e., speed and accuracy) of processing visual information and implementing decisions about the given information. This skill requires the ability to perceive and identify differences between visual information, attention, and visual-motor integration skills to implement decisions on a pencil-and-paper task rapidly (Weschler, 2014). As a construct, processing speed has not been well defined and has been measured through different methods (Shanahan et al., 2006), such as simple reaction time tasks (Snowling, 2008; Weiler et al., 2000) or more complex tasks that require the integration of information (e.g., Trailmaking task, Rapid Automatized Naming tasks; Shanahan et al., 2006). Simple reaction time tasks are often used with very young children (Child et al., 2019). Similar to working memory, processing speed is thought to mediate the relationship between overall cognitive ability and academic achievement by affecting more complex higher order cognitive abilities, such as reasoning and abstract thinking (Luo et al., 2003; Rohde & Thompson, 2007). Other research suggests that processing speed is the link between working memory and overall cognitive ability (Fry & Hale, 1996; Vernon, 1983).

Processing speed abilities have consistently been shown to predict reading fluency skills (Benson, 2007; Caemmerer et al., 2018; Cormier et al., 2017; Niileksela et al., 2016), as well as decoding and reading comprehension skills (Evans et al., 2002; Niileksela et al., 2016). Processing speed abilities have also been shown to predict spelling skills and other writing skills (Cormier et al., 2016; Floyd et al., 2008; Niileksela et al., 2016). Additionally, processing speed abilities have been found to be strong predictors of basic math skills, math fluency, and math problem solving (Floyd et al., 2003; Keith, 1999; McGrew & Hessler, 1995; Niileksela et al., 2016; Taub et al., 2008). These associations have been found to be stronger for younger students, which suggests that processing speed is more important when acquiring new math skills, before skills become more automatic (Bull & Johnston, 1997; Kirby & Becker, 1988).

Visual-Motor Integration (VMI). VMI measures the ability to effectively coordinate vision, perception, and fine motor movements to execute hand/finger tasks (e.g., writing, drawing). VMI is considered a complex skill requiring attention, planning, and inhibition of extraneous movements, as well as a combination of fine motor coordination skills, spatial perception, and reasoning abilities (Sulik et al., 2018). The Beery-Buktenica Developmental Test of Visual-Motor Integration (Beery et al., 2010) is a standardized measure often used to measure this cognitive ability. Although the CHC theory does not include a similar cognitive ability, VMI abilities have consistently been shown to affect academic achievement (Dinehart & Manfra, 2013).

Empirical evidence suggests that VMI is strongly associated with handwriting skills, which have been found to predict general reading and math achievement (Dinehart & Manfra, 2013). Handwriting difficulties have been found impede word learning (Suggate et al., 2016), which is thought to be a consequence of directing attention to motor control and therefore limiting cognitive resources available to focus on reading skills (Wulf & Prinz, 2001). For example, preschool children learning letters by handwriting have been shown to have stronger letter recognition skills than children learning letters by typing, which is thought to provide support for the association between handwriting and reading skills (Longcamp et al., 2005). VMI skills in early kindergarten have been shown to predict reading achievement at the end of the first grade (Son & Meisels, 2006) and are significantly correlated with reading skills and math skills throughout school (Knight & Rizzuto, 1993; Son & Meisels, 2006). Difficulties with VMI have also been associated with difficulties in spelling and writing composition (Berninger et al., 1992).

Behavioural Factors and Academic Underachievement

Inattentive (INA) and hyperactive/impulsive (H/I) behaviours are inconducive to efficient and productive learning and negatively affect academic functioning (APA, 2013; Daley & Birchwood, 2010; Mulholland, 2017). INA and H/I behaviours are core symptoms of ADHD (APA, 2013), with the association between ADHD and academic underachievement having been well-established in the literature (Molina et al., 2009; Shaw et al., 2012). However, accumulating evidence provides substantial support for a negative linear relationship between levels of INA and/or H/I behaviours and academic achievement, regardless of ADHD diagnosis (Merrell et al., 2017; Polderman et al., 2010). Students experiencing high levels of INA and/or H/I without meeting diagnostic threshold for ADHD have been shown to experience academic difficulties similar to those of children meeting diagnostic criteria for ADHD (Merrell et al., 2017; Polderman et al., 2010). The relationship between increasing levels of INA and/or H/I behaviours and increasing difficulties with academic achievement is consistent with the conceptualization that INA and H/I behaviours are dimensional and exist on a continuum (Coghill & Sonuga-Barke, 2012).

A substantial body of literature suggests that INA and H/I behaviours are best viewed as normally distributed traits within the population, with ADHD representing the extreme end of the distribution (Levy et al., 1997; Lubke et al, 2009; Polderman et al., 2007). This conceptualization has been supported by neurobiology studies, that have found a statistically significant relationship between the level of INA and H/I behaviours and delays in peak cortical maturation in children with and without ADHD (Shaw et al., 2011). Support for a continuously distributed trait has also been provided from neuropsychological studies, that demonstrated a linear relationship between reaction times on basic information processing tasks and levels of INA and

H/I behaviours (Salum et al., 2014). Additionally, intervention studies provide no evidence that the effect of behavioural interventions is associated with diagnostic thresholds (McLennan, 2016). Viewing INA and H/I behaviours as a continuum of normally distributed traits provides a better understanding of how increasing levels of INA and/or H/I behaviours could affect academic achievement.

The following section will provide an overview of INA and H/I behaviours and discuss the means by which these behaviours are thought to directly affect academic achievement. The associations between INA and H/I behaviours and certain cognitive abilities, as well as the implications of these associations for academic achievement, will then be discussed.

Inattention. Inattention (INA) refers to the inability to focus or to sustain focus for an extended period of time while ignoring distractions or disruptions in concentration (APA, 2020). INA manifests in the form of behaviours that include distractibility, carelessness, forgetfulness, problems in sustaining attention, deficits in listening to and following instructions, and difficulties in planning, organizing, and completing tasks (APA, 2013; Niggs & Barkley, 2014). Levels of INA are typically measured as the sum of parent-rated and/or teacher-rated observable INA behaviours (Lundervold et al., 2017). The behavioural manifestations of INA are thought to directly affect academic achievement by interfering with the acquisition of fundamental academic skills (APA, 2013; Daley & Birchwood, 2010; Mulholland, 2017). Additionally, INA behaviours are thought to affect academic performance (e.g., grades, teacher-rated progress) through impairments in classroom and academic functioning (Loe & Feldman, 2007).

In terms of academic skills, research studies have consistently demonstrated associations between elevated levels of INA and difficulties in reading, writing, spelling, and math (Carroll et al., 2005; Currie & Stabile, 2006; Daley & Birchwood, 2010; Frazier et al., 2007; Rapport et al., 1999). It has been suggested that INA interferes directly with a child's receptivity to instruction, which is thought to affect the acquisition of the specific skills and knowledge that are necessary for the development of cumulative skills across all academic domains (Isbell et al., 2018; Martinussen et al., 2017; Plourde et al., 2018). For example, an INA student may be distracted, consequently missing an important math concept during instructional time, and fail to develop the cumulative skills necessary for subsequent math tasks. Additionally, children with attentional difficulties are reluctant to engage in tasks that involve sustained mental effort (APA, 2013) and, therefore, spend less time engaged in academic tasks and classroom activities than their typically developing (TD) peers (Lauth et al. 2006). This lack of engagement in academic tasks is thought to adversely affect the acquisition of academic skills and knowledge (Martinussen et al., 2014). For example, research has demonstrated that children with elevated levels of INA engage in less independent reading time than their TD peers (Leonard et al., 2009). The lack of exposure to print, which is associated with reading outcomes across grade levels (Mol & Bus, 2011), is thought to impede the development of word recognition skills (Cunningham & Stanovich, 1991; Martinussen et al., 2014). Overall, decades of research have established an association between elevated levels of INA and impairments in academic skills across all academic domains.

INA also affects academic performance through impairments in classroom functioning (Loe & Feldman, 2007). In the classroom, students with attentional difficulties often demonstrate off-task behaviours and are reluctant to begin classroom activities that involve sustained mental effort (APA, 2013; Kofler et al., 2008). INA students often require frequent redirection or reminders from teachers to stay on task or begin working (APA, 2020). INA students are less likely than their TD peers to complete schoolwork efficiently and accurately (Rapport et al., 1994), which is thought to result from difficulties in paying close attention to details and subsequently making careless mistakes, as well as difficulties listening to and following instructions (DuPaul & Langberg, 2014). Additionally, difficulties with planning and organization behaviours manifest in the form of misplaced homework assignments or school materials necessary to complete tasks, disorganized work areas and schoolbags, difficulties documenting assignment instructions, and impairments in planning strategies to complete assignments (Langberg et al., 2008). Difficulties organizing school materials and behaviours are thought to negatively affect academic functioning (Langberg et al., 2013). Overall, inattentive behaviours are thought to lead to reduced academic productivity, even in the absence of deficits in specific academic skills (DuPaul & Langberg, 2014). These behaviours are often interpreted by parents, teachers, and peers as laziness, disinterest, irresponsibility, non-compliance, or uncooperativeness, and are likely to result in lower grades, familial discord, and peer neglect (APA, 2013).

Research has demonstrated that high levels of INA as early as preschool tend to persist throughout development and often into adolescence (Martel et al., 2012), with some studies reporting increases in INA with increasing age (Larsson et al., 2011; Pingault et al., 2014; Willcutt et al., 2012), particularly during transitions (Langberg et al., 2008). INA behaviours are detected later in the course of development as they become more evident when academic demands increase in formal schooling (Barkley, 1997), which could potentially explain why INA appears to increase with age (Spira & Fischel, 2005). Higher levels of behavioural INA in elementary school are associated with lower scores on standardized tests of academic achievement, lower grades, and continued academic underachievement in high school (Gray et al., 2017). Additionally, high levels of INA as early as kindergarten have been shown to decrease the likelihood of graduating from high school (Pingault et al. 2011). Overall, the presence of elevated levels of INA behaviours have obvious implications for academic functioning and can directly affect academic achievement by interfering with the development of the fundamental academic and behavioural skills essential to learning (APA, 2013; Daley & Birchwood, 2010; Loe & Feldman, 2007; Mulholland, 2017).

Hyperactivity/Impulsivity. Hyperactivity refers to excessive levels of motor activity that lack conscious control; impulsivity refers to excessively rapid reactions to stimuli without prior thought to the potential consequences associated with the reaction (APA, 2013; Tymms et al., 2011). Hyperactivity/Impulsivity (H/I) is typically measured as a single dimension, quantified by parent-rated and/or teacher rated observable H/I behaviours (APA, 2013). H/I manifests in the form of behaviours that include poor control of motor behaviour, which is often demonstrated through behaviours such as excessive fidgeting, tapping, or squirming; running or climbing when it is not appropriate; difficulty remaining seated when sitting is expected; excessive restlessness; excessive talking; and behaviours that demonstrate difficulty prolonging initial reactions or delaying responses to anticipated rewards (APA, 2013; Niggs & Barkley, 2014). Overall, research indicates that children with elevated levels of H/I demonstrate increased gross motor activity compared to their TD peers across settings (e.g., home, school), while sleeping, and when completing laboratory tasks (Corkum & Coulombe, 2013; Cortese et al. 2009; Dane et al. 2000; Imeraj et al. 2011; Porrino et al. 1983; Rapport et al., 2009), regardless of the measurement methodology (e.g., observations, actigraphs) used (Sarver et al., 2015). Although certain research studies have found an association between high levels of H/I behaviours and academic underachievement, this association is not found consistently (Gray et al., 2017; Polderman et al., 2010; Willcutt et al., 2012).

The inconsistent association between H/I and academic achievement could, in part, be attributed to the developmental course of INA and H/I behaviours, as H/I behaviours have been found to be relatively unstable (Willcutt et al., 2012). Specifically, H/I behaviours are more prominent in younger children and tend to decrease with age (APA, 2013). In addition to H/I behaviours decreasing with age, preschool children with high levels of H/I have been found to demonstrate elevated levels of INA behaviours at older ages (Gresham et al., 2005; Spira & Fischel, 2005; Willcutt et al., 2012). This shift is thought to occur because INA behaviours are detected later in the course of development than H/I behaviours as academic demands increase (Barkley et al., 1997; Spira & Fischel, 2005). This shift could potentially explain why certain studies have found that high ratings of H/I behaviours in preschool predicted reading, spelling, and math difficulties throughout school and an increased likelihood of reading and math disabilities (Fischer et al., 1990; McGee et al, 1991). In other words, it could be that potentially undetected INA, which is a known risk factor for academic difficulties (Polderman et al., 2010), is explaining this relationship. Additionally, it has been suggested that the association between H/I behaviours and impairments in academic achievement varies depending on the measure of academic achievement used (Faraone et al., 1998; Willcutt et al., 2012). Students with elevated H/I tend to receive lower scores than their TD peers on subjective measures of academic achievement (e.g., grades), but not on objective measures (e.g., standardized tests of achievement). Overall, certain studies have found a negative relationship between levels of H/I behaviours and scores on reading and math achievement tests (Currie & Stabile, 2006), and children with high levels of H/I behaviours are more likely to have academic impairments compared to children without elevated levels of H/I behaviours (Garner et al., 2013). However, H/I is not thought to influence the acquisition of academic skills (Gray et al., 2017), or at least not to the extent that INA is thought to influence their acquisition (Garner et al., 2013; Polderman et al., 2010).

H/I behaviours are thought to exert an effect on academic functioning through disruptive classroom behaviour, which is assumed to lead to lower grades, remedial education services, grade retention, delinquent behaviour, suspension, expulsion, and school drop-out (Currie & Stabile, 2006; Garner et al., 2013 Willcutt et al., 2012). Given the behaviours associated with H/I, the presence of high levels of H/I behaviours have obvious implications for classroom functioning (APA, 2013; Daley & Birchwood, 2010; Loe & Feldman, 2007; Mulholland, 2017). In the classroom, children with elevated H/I behaviours often demonstrate an overall restlessness in terms of physical and verbal overactivity (APA, 2013; Mulholland et al., 2017). For example, they often fidget or squirm in their seats, leave their seats in situations where sitting is expected (often without permission), and have difficulty engaging in individual seatwork quietly. Instead of completing seatwork quietly, they will often be observed tapping their fingers on their desks, tapping their feet on the floor, or playing with their pencils on their desk (Abikoff et al. 2002). These behaviours are thought to interfere with their ability to complete class tasks and assignments (Junod et al., 2005). Group work is also often problematic, as children with high levels of H/I behaviours frequently talk excessively and have difficulty waiting their turn (APA, 2013; Mulholland et al., 2017). Additionally, they will often respond to the teacher's question before the teacher has finished asking the question, or without raising their hand and waiting for the teacher to call on them (APA, 2013). Although relatively minor compared to other disruptive classroom behaviours (e.g., violent outbursts), this behaviour is rated by teachers (Arbuckle & Little, 2004) as the most disruptive behaviour when it occurs frequently and repeatedly interrupts instruction (Gresham, 2002).

H/I behaviours are among the most common and most disruptive of disruptive classroom behaviours (Arbuckle & Little, 2004) and are thought to impede a student's academic progress (Kremer et al., 2016), as well as the academic progress of non-disruptive students in the class (Hoffman & Lee, 2014). These behaviours are often interpreted by parents, teachers, and peers as defiant, intrusive, and attention-seeking, and are likely to result in lower grades, familial discord, and peer rejection (APA, 2013).

Cognitive Deficits Associated with INA and H/I Behaviours. The behavioural manifestations of INA and H/I, as previously mentioned, have been shown to directly affect academic functioning (Merrell et al., 2017; Polderman et al., 2010). However, INA and H/I are also characterized by impairments in certain cognitive abilities (Biederman et al., 1996). Impairments in certain cognitive abilities are thought to further exacerbate the academic impairments experienced by students with elevated levels of INA and H/I behaviours, as cognitive abilities, as discussed previously, are among the strongest predictors of academic achievement across all academic domains (Deary et al., 2007; Kaufman et al., 2012; Kuncel et al., 2001). Notably, children with high levels of INA and/or H/I have been shown to demonstrate significant working memory (WM) deficits (Kasper et al., 2012; Martinussen et al., 2005), have slower processing speed (PS; Calhoun & Mayes, 2005; Jacobson et al., 2011; Nikolas & Nigg, 2013), exhibit impairments in visual spatial (VS) ability (Quintanar et al., 2006), and have problems with visual-motor integration (VMI; Brossard-Racine et al., 2011).

A recent large-scale meta-analysis investigating the associations between INA-H/I and WM noted that research investigating INA and H/I separately is limited, as the majority of studies conducted in this area investigate these associations within the context of ADHD and often fail to specify which behavioural clusters (i.e., INA or H/I) are included (Kasper et al., 2012). This trend appears to apply to other cognitive abilities as well. Conclusions from the studies that exist appear to demonstrate consistent associations between these cognitive abilities and INA behaviours, and less consistent associations between these abilities and H/I behaviours. For example, associations have consistently been found between high levels of INA behaviours and WM deficits (Rogers et al., 2011), slower PS (Kibby et al., 2019), and difficulties with VS abilities (Chiang et al., 2013; Semrud-Clikeman, 2012). However, the associations between these cognitive abilities and H/I behaviours are less conclusive. Specifically, H/I behaviours have been associated with deficits in aspects of WM (Patros et al., 2017) and slower PS, but this relationship appears to be dependent on the PS measure (Kibby et al., 2019). Associations between H/I and VS abilities have not been found consistently (Chiang et al., 2013; Semrud-Clikeman, 2012). No studies investigating the associations between VMI skills and INA and H/I separately were found. Given the associations between these cognitive abilities and academic achievement, as well as the associations between these cognitive abilities and INA-H/I behaviours, it is important to account for cognitive abilities when investigating the associations between INA-H/I behaviours and academic achievement (Polderman et al., 2010).

Summary

Overall, existing literature has identified several demographic, cognitive, and behavioural factors that are known to predict academic achievement. Although these risk factors have been studied extensively, research investigating these factors together is limited. Studying the associations between academic achievement and each of these risk factors in isolation obscures the interpretation of their unique contributions to academic achievement, as these risk factors not only tend to co-occur, but have also been shown to influence each other. For example, demographic factors such as increasing age, being male, low birthweight, low SES, and single-parent family structure, are known risk-factors for academic underachievement (Polderman et al., 2010). However, the same demographic risk factors have been shown to predict deficits in cognitive abilities (Reynolds et al., 2015) and behavioural difficulties, such as INA and/or H/I (Polderman et al., 2010). Similarly, deficits in certain cognitive abilities have been shown to predict academic underachievement (Reynolds et al., 2015). However, associations have also been found for the same cognitive deficits and INA and/or H/I behaviours (Biederman et al., 1996). Additionally, while certain studies suggest that INA and H/I directly affect academic achievement through the behavioural manifestations of INA and H/I (Daley & Birchwood, 2010; Loe & Feldman, 2007), other studies suggest that the academic impairment experienced by children with these difficulties is a product of deficits in cognitive abilities (Mayes & Calhoun, 2007a; 2007b).

Research also suggests the INA, which is a more robust predictor of academic underachievement than H/I (Garner et al., 2013), is associated with impairments in the acquisition of academic skills, such as reading, spelling, and math (Daley & Birchwood, 2010; APA, 2013; Mulholland, 2017). Questions remain, however, in relation to whether these impairments are a result of INA behaviours (e.g., distractibility, off-task behaviours) or a result of deficits in underlying cognitive processes associated with INA (Biederman et al., 1996), or both. Additionally, research suggests that INA is a normally distributed trait within the population, with ADHD representing the extreme end of the distribution (Lubke et al, 2009; Levy et al., 1997; Polderman et al., 2007). Although several studies have investigated the association between INA and academic achievement within the context of ADHD, a substantially smaller number of studies have investigated this relationship with INA conceptualized as a normally distributed trait, where increasing levels of INA would increase the level of academic underachievement.

Given the importance of successful academic achievement across the lifespan and the known association between INA and academic achievement, the research study that follows aimed to determine whether increased levels of INA and H/I are associated with lower scores in basic reading, spelling, and math skills; and whether this relationship would continue to exist after accounting for background risk factors (age, sex, SES, family structure, and low birthweight), and cognitive processing variables (e.g., working memory, processing speed).

CHAPTER 2. THE CONTRIBUTIONS OF COGNITIVE ABILITIES TO THE RELATIONSHIP BETWEEN INATTENTION AND ACADEMIC ACHIEVEMENT

Academic underachievement is a key indicator of long-term negative functional outcomes across the lifespan. Compared to individuals with higher academic achievement, academically underachieving individuals are more likely to experience employment problems, earn a substantially lower income, depend on government assistance, be involved in criminal activity, use illicit substances, and have poorer health (Lansford et al., 2016). These adverse functional outcomes in adulthood lead to persistent interpersonal difficulties, create familial dysfunction, and place a burden on society through costs associated with government assistance, criminal activity, poor health, and low tax contributions (Karoly et al. 2005; Levin & Belfield 2007). Given that prior academic achievement has been found to be one of the best predictors of future academic success and subsequent graduation (Casillas et al., 2012), and the multitude of adverse psychosocial outcomes associated with academic underachievement across the lifespan, it is imperative to understand which factors increase the risk of academic underachievement. Early identification of students at-risk for academic difficulties is essential to developing timely and effective interventions and providing necessary supports to help students succeed academically.

Academic underachievement has been well documented in students diagnosed with Attention-Deficit/Hyperactivity Disorder (ADHD; Merrell et al., 2017). In fact, academic underachievement is experienced by up to an estimated 80% of students with ADHD (Corkum et al., 2010; DuPaul & Langberg, 2014), and is the main reason students with ADHD are referred for clinical assessment (Loe & Feldman, 2007). ADHD is characterized by persistent, developmentally inappropriate, and functionally impairing levels of inattention and/or hyperactivity and impulsivity (American Psychiatric Association [APA], 2013). Difficulties with attention, hyperactivity, and/or impulsivity are thought to manifest in the form of behaviours that interfere with the development of the fundamental skills essential to learning (Spira & Fischel, 2005). Unsurprisingly, students experiencing high levels of inattention (INA) and/or hyperactivity/impulsivity (H/I) without meeting diagnostic criteria for ADHD experience academic difficulties similar to those of students with formal diagnoses of ADHD (Galera et al., 2009, Loe & Feldman, 2007; Merrell & Tymms, 2001; Pope, 2010). Importantly, it has been suggested that individuals meeting criteria for ADHD compared to individuals not meeting diagnostic threshold represent a quantitative rather than a qualitative difference in terms of associated impairments (Sonuga-Barke & Halperin, 2010).

Behavioural symptoms of INA and H/I, although considered core symptoms of ADHD, are also evident in other disorders, such as: Learning Disabilities (LD; Mayes et al., 1998); Anxiety Disorders (Britton et al., 2012; White et al., 2011); Major Depressive Disorder (MDD; Levin et al., 2007; Nitschke et al., 2001); Obsessive Compulsive Disorder (OCD; Abramovitch et al., 2013); Autism Spectrum Disorder (ASD; Grzadzinski et al., 2011); Obstructive Sleep Disorder (OSD) and other sleep disorders (Precenzano et al., 2016), and exposure to trauma or Post-Traumatic Stress Disorder (PTSD; Szymanski et al., 2011). Students exhibiting symptoms of INA and/or H/I related to these disorders experience academic difficulties similar to students with a formal ADHD diagnosis (Rapport et al.,1999). Additionally, empirical evidence suggests that high levels of INA and H/I can be present in population-based samples without a diagnosis of ADHD or other mental health disorder (Mous et al., 2014). Given the large number of students with behavioural symptoms of INA and H/I, it is important to understand the association between these behaviours and academic achievement at the symptom level rather than at the diagnosis level. Investigating INA and H/I behaviours at the symptom level regardless of clinical diagnosis allows for a better understanding of how these behaviours could potentially lead to future functional impairments, as well as a better understanding of the associations between these behaviours and academic achievement (Schwanz et al., 2007).

Previous studies have demonstrated a negative linear relationship between INA symptom severity (i.e., number of symptoms present) and academic achievement (Merrell et al., 2017; Sayal et al., 2015). More specifically, INA has been found to predict literacy and math achievement (Lan et al., 2011) and has been associated with impairments in the acquisition of reading skills, such as difficulties with decoding, fluency, comprehension, phonological awareness, and vocabulary (Plourde et al., 2015; Willcutt et al., 2007a). Additionally, attention has been found to predict spelling accuracy, handwriting fluency (Noda et al., 2013), and fine-motor control (Fenollar-Cortés et al., 2017). Higher levels of INA as early as kindergarten have been shown to predict long-term reading impairments that persist throughout elementary and often into high school (Rabiner et al., 2000). Additionally, INA has been found to be a stronger predictor of academic difficulties than the presence of an LD (Garner et al., 2013). Symptoms of INA appear to be persistent and have been shown to intensify in adolescence (Rowe & Rowe, l992). Higher levels of teacher-rated INA behaviour have consistently been associated with lower scores on standardized tests of academic achievement and classroom performance outcomes (Gray et al., 2017). Furthermore, teacher-rated INA and/or distractibility in upper-elementary grades have been associated with an increased likelihood of academic underachievement in high-school (Lundervold et al., 2017).

Symptoms of H/I are more prominent in younger children and tend to decrease with age (APA, 2013). Behavioural symptoms of H/I have weaker associations with academic impairments (e.g., reading difficulties, standardized achievement scores) than INA behaviours, but are closely related to disruptive classroom behaviour, lower grades, grade retention, delinquent behaviour, suspension, expulsion, and school drop-out (e.g., Garner et al., 2013 Willcutt et al., 2012). H/I symptoms are stronger predictors of these outcomes than physical health problems, with the associations (except for delinquency) persisting even when scores of H/I symptoms are below diagnostic threshold for ADHD (Currie & Stabile, 2006). Despite the general consensus that symptoms of INA are more robustly associated with academic underachievement than H/I symptoms, certain studies have found associations between high ratings of H/I symptoms and academic achievement (e.g., lower scores on reading and math achievement test scores; reading, spelling, and math difficulties throughout school; increased likelihood of reading and math disabilities; Currie & Stabile, 2006; Fischer et al., 1990; McGee et al, 1991). However, these associations tend to exist when H/I is measured dimensionally, as a continuously distributed trait encompassing behavioural difficulties with hyperactivity, impulsivity, and inattentiveness (Merrell & Tymms, 2001; Saudino & Plomin, 2007; Taylor, 1998). Based on a large body of research, the general consensus regarding the association between symptoms of H/I and academic achievement appears to be that children experiencing difficulties with H/I behaviours have greater academic impairments than students without H/I difficulties, but they are not as academically impaired as students with attention difficulties (Garner et al., 2013; Polderman et al., 2010; Salla et al., 2016).

Academic underachievement has also been associated with deficits in cognitive abilities. Specifically, working memory, processing speed, and visuospatial ability have been identified as cognitive abilities that account for a large proportion of the variance in academic achievement (Rohde & Thompson, 2007). Working memory has been associated with reading ability

(Christopher et al., 2012; Moll et al., 2016; Willcutt et al., 2013), reading comprehension (Christopher et al., 2012), spelling (Wimmer & Schurz, 2010), writing ability (Cornoldi et al., 2010; Re et al., 2014), math problem-solving ability (Moll et al., 2016; Swanson, 2016; Swanson et al., 2019; Willcutt et al., 2013), and listening comprehension (Daneman & Merikle, 1996). Similarly, slow processing speed has been shown to predict reading difficulties in decoding, fluency, and comprehension (Norton & Wolf, 2012), as well as math difficulties (Moll et al., 2016). Likewise, deficits in visual-spatial abilities have been associated with difficulties in mathematics (Cheng & Mix, 2014; Hawes et al., 2017; Zhang et al., 2014), as well as difficulties in reading acquisition (Bellocchi et al., 2017) and spelling (Longcamp et al., 2008). Additionally, visual-motor integration abilities have been found to predict spelling and writing composition scores (Berninger et al., 1992), as well as handwriting skills (Van Hartingsveldt et al., 2015), and general reading and math achievement (Son & Meisels, 2006). Notably, deficits in cognitive abilities tend to co-occur. For example, deficits in working memory and processing speed are often found concurrently, particularly in children with attention difficulties (Katz et al., 2011; Mayes & Calhoun, 2007a; Moll et al., 2016; Willcutt et al., 2005). Deficits in visual-spatial abilities have also been found to co-occur with deficits in working memory and processing speed (Rohde et al., 2007). Similarly, deficits in visual-motor integration abilities often co-occur with difficulties in visual-spatial skills, working memory, and processing speed (Bellocchi et al., 2017; Sulik et al., 2018; Sutton et al., 2011). However, despite the known associations between deficits in multiple cognitive functions, only meta-analyses and reviews tend to examine more than one or two cognitive functions together (Nikolas & Nigg, 2013).

Existing literature has also identified several demographic factors that are associated with academic achievement, regardless of behaviours related to symptoms of INA and/or H/I, learning and other mental health disorders, and cognitive abilities. Increasing age (Polderman et al., 2010), being male (Buchmann et al., 2008), low socioeconomic status (SES; Sirin, 2005; Russell et al., 2015), alternative family structures such as single parent families (Shriner et al., 2010), and low birthweight (Taylor, 2010), have all been associated with academic underachievement. To better understand the associations between INA and H/I behaviours and academic achievement, previous research suggests that studies investigating predictors of academic achievement in children experiencing difficulties with INA and H/I should include demographic factors known to influence academic achievement (Polderman et al., 2010).

In summary, empirical literature has identified several factors that are associated with academic underachievement. An abundance of research has demonstrated associations between academic underachievement and background demographic factors, cognitive factors, and behavioural symptoms of INA and H/I. Despite the abundance of literature, however, very few studies have included demographic, cognitive, and behavioural predictors to determine their unique contributions to academic achievement. Importantly, most studies investigating the associations between academic achievement and INA and H/I at the symptom level have been conducted with community samples of children whose symptom counts are measured based on rating scales of parent- or teacher-rated behavioural symptoms, without having undergone rigorous assessment procedures. The absence of multi-informant rigorous assessment procedures is problematic for several reasons. Parents and teachers observe children in different contexts and tend to rate INA and H/I behaviours differently (Achenbach et al., 1987), which is demonstrated from the low ($r < .30$; Achenbach et al., 1987) to moderate ($r = .40$-$.50$; Bussing et al., 2008) interrater agreement typically observed on rating scales. Also, rating scales have been shown to lack the specificity to sufficiently be used as sole diagnostic instruments (Parker & Corkum, 2013). Overall, conducting detailed clinical interviews with multiple informants (e.g., parents and teachers) to determine symptom severity across settings is thought to be the gold standard for the assessment of INA and H/I symptoms (American Academy of Child and Adolescent Psychiatry [AACAP], 2007; Farone et al., 2015).

Additionally, most studies investigating academic achievement in students experiencing difficulties with INA and/or H/I have investigated these difficulties within the context of ADHD (i.e., symptoms of INA and/or H/I meeting diagnostic threshold). However, these studies often include samples of children without a formal diagnosis of ADHD (i.e., unconfirmed diagnoses assigned for the purposes of the study based on rating scales), who have not undergone rigorous diagnostic procedures. Notably, studies including children with a formal diagnosis of ADHD frequently use INA and H/I symptom counts based on rating scales for the purposes of the study, and often include children who are taking (or have taken) stimulant medications. However, stimulant medications have been shown to improve INA and H/I behaviours to varying degrees (Faraone et al., 2015), which could potentially confound results (Arnold et al., 2020; Polderman et al., 2010). Furthermore, children not meeting diagnostic threshold for ADHD are often excluded from studies, which limits our understanding of the association between academic achievement and symptoms of INA and H/I at the symptom level, as a continuously distributed trait.

The overall objective of the present study was to examine the associations between academic achievement in specific academic domains (i.e., basic reading, spelling, and math skills) and behavioural symptoms of INA and H/I, after accounting for known background risk factors (age, sex, SES, family structure, and low birthweight) and cognitive processes (such as working memory deficits, slower processing speed, impairments in visual-spatial abilities), in a rigorously diagnosed, stimulant medication naïve, clinical sample of elementary school-aged children. This study aimed to answer two research questions: 1) Does the severity of INA or H/I symptoms (i.e., number of symptoms present) predict academic achievement in basic reading, spelling, and math skills in elementary school-aged children? 2) Does the association between INA and/or H/I symptom severity and academic achievement continue to exist after accounting for background risk factors and cognitive processing impairments? To answer these research questions, clinical assessment data from a rigorously diagnosed sample of 354 elementary school-aged children experiencing academic difficulties and behavioural symptoms of INA and/or H/I were analyzed. Based on current existing literature, it was hypothesized that higher scores of INA, not H/I (based on symptoms endorsed on diagnostic interviews with parents and teachers), would be associated with lower scores in basic reading, spelling, and math skills (based on standardized achievement test scores) in elementary school-aged children. It was also hypothesized that higher scores of INA, not H/I (based on symptoms endorsed in diagnostic interviews with parents and teachers), would continue to be associated with lower scores in basic reading, spelling, and math skills (based on standardized achievement test scores) in elementary school-aged children, after accounting for background risk factors (age, sex, SES, family structure, and low birthweight), and cognitive processing variables (e.g., working memory, processing speed).

Method

Participants

Participants in this study consisted of children experiencing difficulties with attention, hyperactivity/impulsivity, and/or learning who were referred to and assessed at the Colchester East Hants Attention-Deficit/Hyperactivity Disorder Clinic (ADHD Clinic) from the time the clinic was developed in 2000 up to June 2019. Children eligible to be assessed at the clinic must have been between 6- and 12-years of age (Grades 1-6) at the time of their assessment; resided within the Colchester East Hants health catchment area; not previously received an ADHD diagnosis; never been on medication for inattention, hyperactivity, impulsivity, or any mental health disorder; and not received a psychoeducational assessment in the two years prior to their clinical assessment. Of note, four participants were enrolled in Grade 7 at the time of their assessment. These students had been referred to the clinic for assessment in prior grades but had progressed to Grade 7 by the time of their assessment due to assessment wait times. It was decided to retain these cases in the analyses as the age of these participants did not exceed 12-years, 11-months. Only children whose parents consented at the time of the assessment to the inclusion of their children's assessment/diagnostic data in potential future research were included in this study. Of the 453 cases included in the clinic's database at the time of this study, nine cases for which parents did not provide consent were excluded from the study.

Measures

Background Information Form

The Background Information Form is a standardized parent self-report questionnaire based on the Family and Household Form from the Ontario Child Health Study (Boyle et al., 1987). The Background Information Form was completed by all parents of children assessed by the ADHD Clinic. Background risk factors that were used in this study as predictors of academic achievement were drawn from this measure. Background data drawn from this measure included: sex (categorical dichotomous variable coded as 0 = *Female*, 1 = *Male*); age (measured in months); family structure (categorical dichotomous variable coded as 0 = *Two-Parent Household*, 1 = *Single-Parent Household*); birthweight (measured in ounces); and SES (measured by the highest level of education of the parent with the highest level of education; categorical variable coded on a scale of 1 to 8 [1 = *some elementary*; 2 = *completed elementary*; 3 = *some secondary*; 4 = *completed secondary*; 5 = *some community or technical college*; 6 = *completed community or technical college*; 7 = *some university or teachers college*; 8 = *completed university or teachers college*]). Parent educational attainment was used as a univariate proxy measure of SES, as education has been found to be the strongest predictor of occupational status and income (Becker et al., 2019; Oakes, n.d.).

Diagnostic Interviews

Two semi-structured diagnostic interviews were conducted as part of the clinical assessment.

Parent Interview for Child Symptoms (PICS; Schachar et al., 2000). The PICS is a semi-structured 3-module diagnostic interview designed to systematically assess symptoms of ADHD and other childhood disorders (e.g., oppositional defiant disorder [ODD], conduct disorder [CD], ASD, various anxiety, depressive, and tic disorders), based on DSM-IV/DSM-5 diagnostic criteria. Administration of the PICS typically requires approximately 1.5-2.5 hours to complete. At the ADHD Clinic, the PICS is administered by a clinical psychologist and a pediatrician, who score parent responses describing the child's behaviour in a variety of situations. The severity of each of the nine INA and nine H/I symptoms is rated on a 3-point scale: 0 = absent; 1 = trivial abnormality; 2 = definite abnormality, with symptoms rated as 2 regarded as clinically significant. The PICS has good reliability for diagnosing mental health disorders in children (Ickowicz et al., 2006).

Teacher Telephone Interview (TTI; Tannock et al., 2002). The TTI is a semi-structured diagnostic interview designed to systematically assess behaviour and functioning in a school setting and assess symptoms of ADHD and other childhood mental health disorders (e.g., ODD, CD, anxiety, depression) based on DSM-IV/DSM-5 diagnostic criteria. The TTI, which is designed to be used in conjunction with the PICS, is administered by a clinical psychologist in a telephone interview with the child's teacher prior to the clinic day. Teacher responses describing the child's behaviour in a school setting are scored on the same scale as the PICS (see above). The TTI-IV has good interscorer (r = .96–.98) and test-retest reliability (r = .79–.95) for ADHD (Hum, 2004).

The PICS and the TTI were used for diagnostic purposes and provided INA and H/I symptom counts for analyses. A symptom was considered present if it was rated as a 2, using the above described 3-point scale. Total parent-rated (PICS) and teacher-rated (TTI) symptom counts for INA and H/I symptoms across the two interviews were combined and used as behavioural predictors of academic achievement (discrete variables indicating total symptom counts for INA and total symptom counts for H/I, ranging from 0 to 18).

Wechsler Intelligence Scale for Children (WISC)

The WISC is an individually administered standardized measure of cognitive ability designed to provide a comprehensive assessment of general intellectual functioning in children from ages 6- to 16-years old. In the current study, standard scores from the four index scores were used as measures of specific cognitive abilities: Verbal Comprehension Index (VCI), Visual Spatial Index (VSI), Working Memory Index (WMI), Processing Speed Index (PSI).

Notably, three versions of the WISC (Wechsler Intelligence Scale for Children – Third Edition [WISC-III], Wechsler, 1991; Wechsler Intelligence Scale for Children – Fourth Edition [WISC-IV], Wechsler, 2003; and Wechsler Intelligence Scale for Children – Fifth Edition [WISC-V], Wechsler, 2014) have been released in the 20 years that the ADHD Clinic has been in operation, all of which have been used by the clinic as measures were updated to reflect current best practices. Given reported correlations on index scores between the WISC-III and WISC-IV (.72-.88; Wechsler, 2003), as well as reported correlations between the WISC-IV and WISC-V (.58-.85; Wechsler, 2014), standardized data obtained from the WISC-III, WISC-IV, and WISC-V were used in the current study as measures of cognitive abilities.

Also of note, the most recent version of the WISC separated the Perceptual Reasoning Index (PRI) from the previous version (WISC-IV) into the Visual Spatial Index (VSI) and the Fluid Reasoning Index (FRI). Given that the PRI and the VSI are similar conceptually (i.e., measure the ability to evaluate visual details and to understand visual spatial relationships to construct designs from a model; Weschler, 2014), and given the higher reported correlation (Wechsler, 2014) between the PRI and VSI (.73) compared to the correlation between PRI and FRI (.58), it was decided to include VSI (WISC-V) and PRI (WISC-IV) as measures of the same cognitive ability. The FRI from the WISC-V was not included in this study as a measure of cognitive abilities.

Beery-Buktenica Developmental Test of Visual-Motor Integration (VMI)

The VMI is a standardized measure of visual perceptual and motor abilities designed to assess the ability to effectively coordinate vision, perception, and fine motor movements to execute hand/finger tasks (e.g., writing, drawing), referred to as visual-motor integration. The VMI can be administered to children and adults from ages 2- to 100-years and consists of one primary and two supplemental subtests. Only the standard score for the primary subtest (Test of Visual-Motor Integration; VMI), in which the task requires the individual to copy designated geometric shapes of increasing complexity, was used in this study. The VMI has demonstrated good inter-rater and test-retest reliability, and good concurrent and construct validity. Although three editions of the measure have been used by the clinic in the 20 years it has been in operation, all editions of the VMI contain the exact same items and reported correlations with the two previous editions are high (.98 and .99 respectively; Beery et al., 2010). Therefore, standard scores from the VMI-4, VMI-5, and VMI-6 were used in the current study as a measure of visual-motor integration.

The four WISC indices (VCI, VSI, WMI, PSI) and VMI index, all of which are measured in standard scores (*M* = 100, *SD* = 15), were used as cognitive predictors of academic achievement.

Wechsler Individual Achievement Test (WIAT)

The WIAT is an individually administered academic achievement test designed to assess listening, speaking, reading, writing, spelling, and mathematics skills in individuals 4- to 50-years old. Standard scores from three WIAT subtests were used as indicators of academic achievement: WIAT Word Reading subtest scores were used as a measure of reading; WIAT Spelling subtest scores were used as a measure of spelling; and WIAT Numerical Operations subtest scores were used as a measure of mathematics. WIAT scores are represented in standard scores (*M* = 100, *SD* = 15).

The WIAT–III is a revision of the Wechsler Individual Achievement Test – Second Edition (WIAT–II; Wechsler, 2001), which has also been used in assessments at the ADHD Clinic. The WIAT-II and WIAT-III have been found to have high internal consistency and test-retest reliability (Wechsler, 2009; Wechsler, 2001). Each version of the WIAT is co-normed with and empirically linked to the version of the WISC in use during the same period (i.e., WIAT-II with WISC-III and WISC-IV; WIAT-III with WISC-IV and WISC-IV), allowing for valid and reliable comparison between achievement and ability (Wechsler, 1991; Wechsler, 2014;

Wechsler, 2009). Additionally, given reported correlations between the WIAT-II and WIAT-III on subtest scores (.42 to .87; Wechsler, 2009), data obtained from WIAT-II and WIAT-III will be used in the current study as outcome measures of academic achievement.

Procedure

Full ethical approval for this study was granted through the Nova Scotia Health Authority and Mount Saint Vincent University Research Ethics Boards.

The current study is an archival data analysis study. Data for this study were drawn from the ADHD Clinic's clinical/research database, which included assessment and diagnostic data of children assessed by the clinic between 2000-2019. Assessments completed at the clinic were comprehensive and rigorous, using recommended evidence-based assessment guidelines and an interdisciplinary diagnostic approach. In brief, prior to arriving at the ADHD Clinic, the participants' parent/s and teacher/s completed screening measures (Conners Parent and Teacher Rating Scales; Conners, 1997) and a demographic questionnaire (Background Information Form). Each assessment included a review of the child's school records and a classroom observation, semi-structured diagnostic interviews with the child's parent/s (PICS) and teacher/s (TTI), and a standardized psycho-educational assessment battery with the child (WISC, VMI, WIAT). A detailed description of this clinic can be found in McGonnell et al., 2009.

Statistical Analyses

Data for the current study were analyzed using MS Excel (version 16.38) and IBM SPSS software (version 26). Data were drawn from the ADHD Clinic's clinical/research database. Descriptive statistics were first computed to provide an overview of the sample characteristics. Prior to conducting analyses, the pattern of missing data was examined using Little's Missing Completely at Random (MCAR) test (Little, 1988; Little & Ruben, 2002), which indicated that the data were missing at random, $\chi^2(91) = 94.710$, $p = .37$. Cases with missing values ($n = 90$) were excluded from the study. Additionally, assumptions for hierarchical multiple linear regressions were tested (i.e., linear relationship between predictor and outcome variables, multivariate normality, absence of multicollinearity, and homoscedasticity) and all assumptions were met.

Hypothesis 1

Higher scores of INA, not H/I (based on symptoms endorsed in diagnostic interviews with parents and teachers), will be associated with lower scores in basic reading, spelling, and math skills (based on standardized achievement test scores) in elementary school-aged children.

Three multiple linear regressions (reading, spelling, and math) were conducted to evaluate the associations between academic achievement and symptom severity of INA and H/I.

Dependent Variables. Three WIAT subtests (the *Word Reading* subtest as a measure of reading, the *Spelling* subtest as a measure of spelling, and the *Numerical Operations* subtest as a measure of math) were used as dependent variables in each of the regressions respectively.

Independent Variables. Total parent-rated (PICS) and teacher-rated (TTI) symptom counts for INA and H/I symptoms endorsed across the two interviews were used as behavioural predictors of academic achievement.

Hypothesis 2

Higher scores of INA, not H/I (based on symptoms endorsed in diagnostic interviews with parents and teachers), will continue to be associated with lower scores in basic reading, spelling, and math skills (based on standardized achievement test scores) in elementary school-aged children, after accounting for background risk factors (age, sex, SES, family structure, and low birthweight), and cognitive processing variables (WISC VCI, VSI, WMI, and PSI scores, and VMI score).

Three hierarchical multiple linear regressions were conducted to evaluate the contribution of INA and H/I on reading, spelling, and math (based on standardized achievement test scores) after accounting for background risk-factors and cognitive factors.

Dependent Variables. Three WIAT subtests (the *Word Reading* subtest as a measure of reading, the *Spelling* subtest as a measure of spelling, and the *Numerical Operations* subtest as a measure of math) were used as dependent variables in each of the regressions respectively.

Independent Variables. The same independent variables were entered in each step of each of the three regressions. Background risk-factors were entered in the first step. Variables included in this predictor domain were sex, age, SES, family structure, and birthweight. Cognitive variables were entered in the second step of the regressions. The four WISC index scores (VCI, VSI, WMI, PSI) and the VMI index score were used as cognitive predictors of academic achievement. Behavioural variables were entered in the third step of the regressions. Total parent-rated (PICS) and teacher-rated (TTI) symptom counts for INA and H/I symptoms endorsed across the two interviews were used as behavioural predictors of academic achievement.

Results

Sample Characteristics

Participants consisted of children experiencing difficulties with INA, H/I, and/or learning who were referred to and assessed by the ADHD Clinic. The final sample consisted 354 participants between the ages of 5-years, 5-months and 12-years, 7-months (M = 8.56, SD = 1.62). The majority of participants (n = 247, 70%) were male and 107 (30%) were female.

Participant birthweight ranged from 2 lbs. 4 oz. to 11 lbs. 1 oz. (*M* = 7.55, *SD* = 1.41). Twenty-eight (0.6%) participants were born at a weight that is considered low birthweight (i.e., below 2500 grams, or 5 lbs. 8 oz.). Participant grade level ranged from Grade Primary to Grade 7 (*M* = 2.82, *SD* = 1.62). The majority of participants (*n* = 282, 80%) were from 2-parent families, and on average, parents had completed community or technical college. Demographic characteristics of the final sample (*N* = 354) are summarized in Table 1.

Sample Clinical Description

Diagnoses and Comorbidities

Overall, 52% of participants (*n* = 184) met diagnostic criteria for ADHD. Of participants meeting diagnostic criteria for ADHD, 40% (*n* = 74) did not meet criteria for a comorbid LD or other mental health (MH) disorder. Additionally, 53% of participants (*n* = 186) met diagnostic criteria for LD. Of participants meeting diagnostic criteria for LD, 38% (*n* = 70) did not meet criteria for a comorbid MH disorder. Furthermore, 29% of participants (*n* = 103) met diagnostic criteria for MH disorders other than ADHD or LD. Of participants meeting diagnostic criteria for MH disorders other than ADHD or LD, 25% (*n* = 26) met criteria for only one other MH diagnosis. Thirty-seven participants (11%) did not meet diagnostic criteria for any MH diagnosis. A clinical description of the sample indicating the number and percentages of the MH diagnoses the sample received is summarized in Table 2. The numbers and percentages of comorbid diagnoses the sample received are summarized in Table 3.

Behavioural Symptoms (INA and H/I)

Combined parent and teacher ratings of INA and H/I symptoms indicated a mean symptom count of 10.23 (*SD* = 4.44) for INA and 8.10 (*SD* = 5.20) for H/I. Means, standard deviations, and minimum and maximum scores for INA and H/I symptoms based on parent-rated (PICS) and teacher-rated (TTI) behaviours are summarized in Table 4.

Cognitive Ability

Participant mean standard scores on WISC and VMI indices ranged from 90.96 to 100.17, with participants scoring the lowest on the PSI and scoring the highest on the VCI. Means, standard deviations, and minimum and maximum scores for WISC and VMI indices are summarized in Table 5.

Academic Achievement

Participants mean standard scores on WIAT subtests ranged from 88.06 to 93.63, with participants scoring the lowest on the *Numerical Operations* subtest and scoring the highest on the *Word Reading* subtest. Overall, underachievement (i.e., scores of one or more standard deviations below the mean) ranged from 31-38% across subtests. Specifically, 31% (n = 108) of participants were underachieving on the *Word Reading* subtest, 34% (n = 120) of participants were underachieving on the *Spelling* subtest, and 38% (n = 136) of participants were underachieving on the *Numerical Operations* subtest. Means, standard deviations, and minimum and maximum scores for WIAT subtests (*Word Reading*, *Numerical Operations*, and *Spelling*) are summarized in Table 6.

Hypothesis 1

Three multiple linear regression analyses were conducted to test the hypothesis that higher scores of INA, not H/I (based on symptoms endorsed in diagnostic interviews with parents and teachers), will be associated with lower scores in basic reading, spelling, and math skills (based on standardized achievement test scores) in elementary school-aged children. WIAT reading, spelling, and math subtest standard scores were used as outcome variables in each regression respectively.

Reading (WIAT Word Reading). Results indicated that INA and H/I accounted for 3% of the variance, which was statistically significant, $F(2, 351) = 5.11$, $p = .006$, $R^2 = .03$. Both INA and H/I were significant predictors of reading scores. INA, $\beta = -.16$, $t(351) = -2.75$, $p = .006$, decreased reading scores by .57 standard scores, 95% C.I. [-.98, -.16], for each symptom increase in INA symptom count. H/I, $\beta = .15$, $t(351) = 2.65$, $p = .008$, increased reading scores by .47 standard scores, 95% C.I. [.12, .82], for each symptom increase in H/I symptom count.

Spelling (WIAT Spelling subtest). Results indicated that INA and H/I accounted for 2% of the variance, which was statistically significant, $F(2, 351) = 3.70$, $p = .03$, $R^2 = .02$. Both INA and H/I were significant predictors of spelling scores. INA, $\beta = -.13$, $t(351) = -2.18$, $p = .03$, decreased spelling scores by .40 standard scores, 95% C.I. [-.75, -.04], for each symptom increase in INA symptom count. H/I, $\beta = .14$, $t(351) = 2.40$, $p = .02$, increased spelling scores by .37 standard scores, 95% C.I. [.07, .68], for each symptom increase in H/I symptom count.

Math (WIAT Numerical Operations subtest). Results indicated that INA and H/I accounted for 2% of the variance, which was statistically significant, $F(2, 351) = 3.61$, $p = .03$, $R^2 = .02$. INA significantly predicted math scores, $\beta = -.15$, $t(351) = -2.56$, $p = .01$, with math scores decreasing .46 standard scores, 95% C.I. [-.81, -.11], for each symptom increase in INA symptom count. H/I was not a significant predictor of math scores.

Hypothesis 2

To test the second hypothesis, that higher scores of INA, not H/I (based on symptoms endorsed in diagnostic interviews with parents and teachers), will continue to be associated with lower scores in basic reading, spelling, and math skills (based on standardized achievement test scores) in elementary school-aged children, after accounting for background risk factors (age, sex, SES, family structure, and low birthweight), and cognitive processing variables (e.g., working memory, processing speed), three hierarchical multiple linear regressions were conducted. WIAT reading, spelling, and math subtest standard scores were used as outcome variables in each regression respectively.

Reading (WIAT Word Reading). Model 1 (background risk-factors) accounted for 3% of the variance and was statistically significant, $F(5, 348) = 2.28$, $p = .047$, $R^2 = .03$. Sex was a significant predictor of reading, $\beta = .12$, $t(348) = 2.15$, $p = .03$, with males scoring 4.00 points, 95% C.I. [.34, 7.65] higher than females. Age, SES, birthweight, and family structure were not significant predictors in Model 1.

Model 2 (cognitive factors) accounted for 35% of the variance and was statistically significant, $\Delta F(5, 343) = 38.01$, $p < .001$, $\Delta R^2 = .35$. Significant predictors in Model 2 were: VCI, $\beta = .36$, $t(343) = 6.57$, $p < .001$, with reading scores increasing .45 points, 95% C.I. [.31, .58], for every standard score increase in VCI; WMI, $\beta = .29$, $t(343) = 5.62$, $p < .001$] with reading scores increasing .36 points, 95% C.I. [.24, .49], for every standard score increase in WMI; and VMI, $\beta = .12$, $t(343) = 2.40$, $p = .02$, with reading scores increasing .12 points, 95% C.I. [.03, .30] for every standard score increase in VMI. VSI and PSI were not significant predictors in Model 2. Sex, which was a significant predictor in Model 1, was no longer significant after the cognitive variables were added to Model 2, nor were any of the other background variables entered in step one.

Model 3, in which scores for total INA symptom count and total H/I symptom count were added to the model, accounted for 0.7% of the variance and was not statistically significant, $\Delta F(2, 341) = 2.06$, $p = .13$, $\Delta R^2 = .007$.

Spelling (WIAT Spelling subtest). Model 1 (background risk-factors) accounted for 2% of the variance and was not statistically significant, $F(5, 348) = 1.47$, $p > .20$, $R^2 = .02$.

Model 2 (cognitive factors) accounted for 28% of the variance and was statistically significant, $\Delta F(5, 343) = 27.10$, $p < .001$, $\Delta R^2 = .28$. Significant predictors in Model 2 were: VCI, $\beta = .25$, $t(343) = 4.20$, $p < .001$, with spelling standard scores increasing .26 points, 95% C.I. [.14, .39] for every standard score increase in VCI; WMI, $\beta = .31$, $t(343) = 5.66$, $p < .001$, with spelling standard scores increasing .34 points, 95% C.I. [.22, .45] for every standard score increase in WMI; and VMI, [$\beta = .17$, $t(343) = 3.14$, $p = .002$] with spelling standard scores increasing .19 points, 95% C.I. [.07, .31], for every standard score increase in VMI. VSI and PSI scores were not significant predictors in Model 2. Age, which was statistically significant in Model 1 (although Model 1 was not significant), remained significant in Model 2. Additionally, SES (measured by highest level of parent education; 1 = some elementary; 8 = completed university or teacher's college) was a significant predictor of spelling scores, $\beta = -.15$, $t(343) = -3.11$, $p = .002$, with spelling standard scores decreasing by 1.26 points, 95% C.I. [-2.05, -.46], for every point increase in level of parent education.

Model 3, in which total INA and H/I symptom counts were added to the model, accounted for 0.3% of the variance and was not statistically significant, $\Delta F(2, 341) = .74$, $p = .48$, $\Delta R^2 = .003$.

Math (WIAT Numerical Operations subtest). Model 1 (background risk-factors) accounted for 9% of the variance and was statistically significant, $F(5, 348) = 6.86$, $p > .001$, $R^2 = .09$. Significant predictors in Model 1 were sex, $\beta = .12$, $t(348) = 2.38$, $p = .02$, with males scoring 3.65 standard scores, 95% C.I. [.63, 6.66], higher than females; age, $\beta = -.21$, $t(348) =$

-4.14, $p < .001$, with math scores decreasing .15 standard scores, 95% C.I. [-.22, -.08], for each month increase in age; and SES, $\beta = .13$, $t(348) = 2.55$, $p = .01$, with math scores increasing 1.10 standard scores, 95% C.I. [.25, 1.95], for every point increase in level of parent education. Birthweight and family structure were not significant predictors in Model 1.

Model 2 (cognitive factors) accounted for 31% of the variance and was statistically significant, ΔF (5, 343) = 34.65, $p < .001$, $\Delta R^2 = .31$. All cognitive variables entered in Model 2 were significant predictors of math scores. VCI significantly predicted math scores, $\beta = .20$, $t(343) = 3.59$, $p < .001$, with math scores increasing .20 standard scores, 95% C.I. [.02, .32], for each standard score increase in VCI; VSI significantly predicted math scores, $\beta = .14$, $t(343) = 2.41$, $p = .02$, with math scores increasing .14 standard scores [95% C.I. (.03, .25)] for each standard score increase in VSI; WMI significantly predicted math scores, $\beta = .21$, $t(343) = 4.12$, $p < .001$, with math scores increasing .22 standard scores 95% C.I. [.12, .33] for each standard score increase in WMI; PSI significantly predicted math scores, $\beta = .13$, $t(343) = 2.69$, $p = .007$, with math scores increasing .13 standard scores, 95% C.I. [.04, .23], for each standard score increase in PSI; and VMI significantly predicted math scores, $\beta = .12$, $t(343) = 2.31$, $p = .02$, with math scores increasing .13 standard scores, 95% C.I. [.02, .24], for each standard score increase in VMI. Sex and age, which were statistically significant predictors in Model 1 remained significant in Model 2. SES (statistically significant in Model 1) was not a significant predictor in Model 2, nor were family structure or birthweight.

Model 3, in which total INA and H/I symptom counts were added to the model, accounted for 2% of the variance and was statistically significant, ΔF (2, 341) = 4.24, $p = .02$, $\Delta R^2 = .02$. H/I significantly predicted math scores, $\beta = -.13$, $t(341) = -2.60$, $p = .01$, with math scores decreasing .34 standard scores, 95% C.I. [-.60, -.08], for each symptom increase in H/I symptom count. Cognitive scores entered in Model 2 remained significant in Model 3. Additionally, sex and age remained statistically significant predictors in Model 3.

Results of hierarchical multiple linear regression analyses for the three outcome variables (reading, spelling, and mathematics) are summarized in Table 7.

Discussion

The overall goal of the present study was to determine whether increased levels of behavioural symptoms of INA and H/I were associated with lower scores on standardized tests of achievement in basic reading, spelling, and math skills, after accounting for known background risk factors and cognitive processes. Behavioural symptoms of INA and H/I were based on symptoms endorsed on diagnostic interviews with parents and teachers; background risk factors included age, sex, SES, family structure, and low birthweight; and cognitive variables were based on index scores (VCI, VSI, WMI, PSI, and VMI) from standardized measures of cognitive ability. To examine these associations, clinical assessment data from a rigorously diagnosed, stimulant medication naïve sample of 354 elementary school-aged children experiencing academic difficulties and behavioural symptoms of INA and/or H/I were analyzed. It was expected that a) higher scores of INA, not H/I, would be associated with lower scores in basic reading, spelling, and math skills, and that b) these associations would persist after accounting for known background risk factors and cognitive processing variables.

As expected, results indicated that higher levels of INA (before accounting for background risk factors and cognitive variables) significantly predicted lower scores in basic reading, spelling, and math skills, providing support for the first hypothesis. This finding is consistent with an abundance of previous research that has demonstrated a negative linear relationship between INA symptom severity and academic achievement (Lan et al., 2011;

Merrell et al., 2017; Noda et al., 2013; Plourde et al., 2015; Sayal et al., 2015; Willcutt et al., 2007a). This finding provides further support for the well-established association between INA and academic underachievement, as well as the robustness of INA as a predictor of underachievement across academic domains, as increasing levels of INA predicted lower scores in all three academic skills assessed (reading, spelling, and math). Conversely, higher levels of H/I behaviours were not expected to predict academic underachievement, as previous research has demonstrated weak associations between H/I and academic achievement (Garner et al., 2013; Polderman et al., 2010). Consistent with previous research (e.g., Merrell et al., 2017), higher levels of H/I were not associated with lower scores in math. Interestingly however, higher scores of H/I significantly predicted higher scores in reading and spelling skills. This finding was unexpected.

A possible explanation for this unexpected finding comes from a body of research suggesting that certain H/I behaviours could potentially be advantageous to academic achievement (Tymms & Merrell, 2011). Specifically, it has been suggested that the DSM-IV/DSM-5 item "Often blurts out an answer before a question has been completed" (APA, 2013, p. 60) could be conceptualized as a form of cognitive impulsivity, potentially indicating the ability to compute answers rapidly, manifesting in the form of an overt impulsive behaviour (Merrell & Tymms, 2005; Oades et al., 2008; Tymms & Merrell, 2011). A study conducted by Tymms and Merrell (2011) that investigated the relationships between academic achievement and INA and H/I by examining the unique contributions of specific DSM-IV/DSM-5 items separately found that impulsivity was positively associated with reading and math outcomes. Specifically, they found that while higher levels of INA were strongly associated with lower scores in reading and math, higher levels of hyperactivity were not associated with math scores and weakly associated with reading scores, and higher levels of impulsivity were associated with higher scores in both outcomes. This study then compared each of the three DSM-IV/DSM-5 impulsivity items separately and found that the item "Often blurts out an answer before a question has been completed" had the strongest positive associations with reading and math scores after controlling for INA. Although the authors note that further research is necessary before concluding that specific impulsive behaviours could be advantageous to academic achievement, this research offers a potential explanation to the finding of the current study, where higher levels of H/I were associated with higher scores in reading and spelling. The data available from the current study, however, do not allow for this analysis.

It was also expected that higher scores of INA, not H/I, would continue to be associated with lower scores in basic reading, spelling, and math skills after accounting for background risk factors and cognitive processing variables (hypothesis 2). This hypothesis was not supported. More specifically, although higher scores of INA were significantly associated with lower scores in reading, spelling, and math initially (confirming the first hypothesis), these associations did not persist when cognitive variables were added to the models. Overall, cognitive variables accounted for the majority of the variance across the three academic domains (basic reading, spelling, math skills). Specifically, VCI, WMI, and VMI were statistically significant predictors for reading and spelling, and all cognitive variables (VCI, VSI, WMI, PSI, and VMI) were statistically significant predictors for math. Although the hypothesis that higher levels of INA would continue to predict basic reading, spelling, and math scores after accounting for background and cognitive variables was not supported, several potential interpretations could explain this finding.

One interpretation of this finding is based on a body of literature that suggests that subjectively measured INA behaviours alone cannot solely account for the academic underachievement experienced by students with high levels of INA behaviours (Preston et al., 2009; Steele et al., 2012). Notably, INA behaviour reduction through treatment with stimulant medication produces questionable improvements on academic achievement, particularly on standardized measures of achievement (Barnard-Brak & Brak, 2011; Corkum et al., 2010; Currie et al., 2013; Loe & Feldman, 2007). Continued academic underachievement despite the reduction of INA behaviours raises the question of which other factors are contributing to the academic impairments evident in students with high levels of INA behaviours. Empirical research has suggested that academic underachievement experienced by children with high levels of INA is a product of deficits in cognitive abilities, as INA is thought to be characterized by underlying impairments in cognitive abilities (Mayes & Calhoun, 2007a; 2007b; Preston et al., 2011).

Specifically, research has consistently demonstrated associations between INA and deficits in working memory, processing speed, visual spatial abilities, and visual-motor integration skills (Brossard-Racine et al., 2011; Chiang et al., 2013; Semrud-Clikeman, 2012; Kibby et al., 2019; Rogers et al., 2011). Deficits in these cognitive abilities, however, have also been associated with academic underachievement in reading (Bellocchi et al., 2017; Christopher et al., 2012; Moll et al., 2016; Norton & Wolf, 2012; Son & Meisels, 2006; Willcutt et al., 2013), spelling (Berninger et al., 1992; Longcamp et al., 2008; Wimmer et al., 2010), and math (Cheng & Mix, 2014; Hawes et al., 2017; Moll et al., 2016; Son & Meisels, 2006; Swanson, 2016; Swanson et al., 2019; Willcutt et al., 2013; Zhang et al., 2014). Given the associations between high levels of INA and deficits in cognitive abilities, as well as the associations between academic underachievement and deficits in cognitive abilities, it is likely that deficits in cognitive abilities associated with INA are driving the relationship between high levels of INA and academic underachievement, as previously suggested by Mayes and Calhoun (2007a; 2007b). This conceptualization of the associations between INA, cognitive deficits, and academic underachievement is consistent with the results of the present study, in which cognitive variables accounted for the largest proportion of the variance in academic achievement.

Another interpretation of this finding could be that cognitive factors are stronger predictors of academic achievement than INA at the developmental stage of the present sample. The majority of the sample consisted of children in lower elementary grades (Grade 2 on average), and INA is thought to exert a greater effect on academic achievement as academic demands increase in higher grades (Barkley et al., 1997; Spira & Fischel, 2007). The age of the participants could also potentially explain the relatively low proportion of the variance (2-3%) that INA accounted for initially before including the demographic and cognitive variables to the models. Additionally, research including subjectively measured INA behaviours (i.e., based on parent- and/or teacher-rated behaviours) as well as objectively measured INA (i.e., based on tasks thought to be tapping into distinct aspects of attentional processes, namely sustained, selective, and executive attention) demonstrated that, while objective measures significantly predicted reading and math outcomes, subjective measures did not predict these outcomes after accounting for cognitive factors (Preston et al., 2011; Steele et al., 2012). The finding that subjectively measured INA behaviours were not associated with reading and math outcomes is consistent with the present study.

Higher levels of H/I behaviours were not expected to be associated with lower scores on basic reading, spelling, and math skills, as previous research suggests that H/I is an inconsistent predictor of academic achievement (Garner et al., 2013; Gray et al., 2017; Polderman et al., 2010). As expected, higher levels of H/I did not significantly predict reading and spelling scores. However, results indicated that higher levels of H/I significantly predicted lower scores in math. Although this finding was unexpected, it is not entirely surprising. Several studies have demonstrated associations, albeit inconsistently, between increasing levels of H/I and decreased math scores (Currie & Stabile, 2006; Saudino & Plomin, 2007). Furthermore, students with high levels of H/I behaviours tend to make careless mistakes on math tasks, which could potentially explain this association.

Previous research has stressed the importance of including background risk factors as covariates in research investigating INA and academic achievement to avoid potential confounds (Polderman et al., 2010). In the present study, background demographic variables were not consistently associated with academic achievement across academic domains, with associations varying across outcomes. For example, no background variable was significantly associated with reading scores after cognitive variables were added to the model. For spelling, age and SES were significant predictors when cognitive variables were added to the model. The association between spelling and SES (measured by the highest level of educational attainment of the parent with the highest education), however, was in the opposite direction than what would be expected. Specifically, spelling scores decreased as SES increased. This finding was unexpected and counterintuitive, and no precedence was found in the literature to explain this association. Furthermore, although math scores were initially associated with age, sex, and SES, only age and sex continued to be associated with math scores when cognitive and behavioural variables were added to the model. Overall, background demographic variables identified by previous research as risk factors for academic achievement were inconsistently associated with reading, spelling, and math scores. Specific background risk factors were associated with specific academic outcomes, with a greater number of background risk factors associated with math scores. Nevertheless, it was decided to retain the background risk factors as covariates in the models as research suggests that these variables are known to affect both, INA and academic achievement, to varying degrees (Duncan et al., 2007; Warner-Rogers et al., 2000).

Notably, although the entire sample consisted of children suspected of having ADHD who were referred for an ADHD assessment, only approximately half the sample met diagnostic criteria for ADHD. An almost equal proportion of children met diagnostic criteria for LD, and close to one third of the sample met criteria for Mental Health (MH) disorders other than ADHD or LD (such as ODD, GAD, ASD, Sleep Disorders, and other MH disorders). Of note, close to two thirds of children meeting diagnostic criteria for ADHD or LD also met criteria for at least one comorbid diagnosis. Importantly, during screening procedures implemented to determine eligibility for clinical assessment, the entire sample met criteria for ADHD based on parent- and/or teacher-rated behaviours on rating scales. In sum, although the entire sample appeared to present with high levels of INA and H/I behaviours and were considered to have ADHD based on behavioural rating scales, comprehensive clinical assessment procedures determined that not all INA and H/I behaviours warranted an ADHD diagnosis. This finding highlights the fact that parent- and/or teacher-rated INA and H/I behaviours are not necessarily indicative of ADHD, as INA and H/I behaviours are also characteristic of conditions and MH disorders other than ADHD. Additionally, rating scales lack the specificity to sufficiently be used as a sole diagnostic instrument (Parker & Corkum, 2013). The clinical description of this sample underscores the importance of comprehensive, evidence-based, differential diagnostic procedures to determine accurate diagnoses and appropriate interventions.

Additionally, between 31-38% of children in this sample were underachieving (i.e., scores of one or more standard deviation below the mean) in specific academic domains, with the greatest proportion underachieving in math, and the lowest proportion underachieving in reading (31% in reading, 34% in spelling, and 38% in math). Given that the sample in this study consisted of children experiencing teacher-rated academic difficulties and high levels of INA and/or H/I behaviours, it would be expected that this proportion would be higher, as studies have reported that as many as 80% of students with these difficulties experience academic impairments (Corkum et al., 2010; DuPaul & Langberg, 2014). This finding highlights the importance of standardized testing, as teacher-rated underachievement based on subjective measures (commonly referred to as academic performance; e.g., grades, assignment quality, homework completion, classroom functioning) do not necessarily indicate deficits in academic skills (Langberg et al., 2011). Although subjective measures are important indicators of future academic success and educational attainment (Casillas et al., 2012), they are often unable to accurately quantify academic skills (Langberg et al., 2011). Therefore, when deficits in academic skills are suspected, standardized achievement tests should be included in comprehensive assessments to determine the presence or absence of academic impairments. Importantly, identifying deficits in specific skills is essential to determining appropriate interventions.

Strengths, Limitations, and Future Direction

The present study had several strengths. This study included a large, rigorously diagnosed, stimulant medication naïve clinical sample. Notably, very few studies investigating the association between INA and H/I behaviours and academic achievement include rigorously diagnosed samples, and even fewer studies include rigorously diagnosed samples of this size. The large sample size (N = 354) increases the generalizability and accuracy of the results.

Additionally, the comprehensive, evidence-based assessment methods implemented during the assessment process, which included diagnostic interviews based on parent- and teacher-rated behaviours and classroom observations, are considered the gold standard in assessment and diagnosis of ADHD (AACAP, 2007; Farone et al., 2015), and increase the accuracy and validity of the INA and H/I symptom counts included in this study. Also, although the sample in the current sample was a clinical sample, INA and H/I behaviours were measured as a continuously distributed trait and participants not meeting diagnostic threshold were not excluded, as research suggests that these behaviours exist across a continuum (Coghill & Sonuga-Barke, 2012). This dimensional approach to measuring INA and H/I behaviours allows for a better understanding of the impairments associated with increasing levels of these behaviours, and increases the generalizability of the study, as INA and H/I behaviours are thought to be a continuously distributed trait (Lubke et al, 2009; Levy et al., 1997; Polderman et al., 2007).

Previous research has highlighted the importance of including risk factors known to influence both, academic achievement, as well as INA and H/I behaviours, as covariates in studies investigating the associations between these behaviours and academic achievement (Polderman et al., 2010). This issue was addressed in the present study, which included known risk factors and accounted for their unique contribution to academic achievement. Also of note, academic achievement in this study was measured by standardized achievement tests, which provide accurate quantifications of deficits in academic skills, and can be compared across studies. Additionally, the use of standardized achievement measures holds clinical utility, as they are frequently used to determine diagnoses in clinical and educational settings, and therefore increase the ecological validity of this study.

Certain limitations to the present should be acknowledged. Notably, although the dimensional measurement of INA and H/I behaviours allowed for the inclusion of all participants assessed by the clinic, the sample in this study was, nonetheless, a clinically referred sample of children suspected of ADHD. Therefore, it is likely that the INA and H/I symptom counts in this study were elevated compared to INA and H/I behaviours in the general population. Future research should consider including non-referred children in addition to clinically referred children to investigate these associations. Additionally, the present sample consisted of children in lower elementary grades who were, on average, enrolled in Grade 2. However, research suggests that INA is more important to academic achievement as academic demands increase in higher grades, and INA behaviours often become more evident at later developmental stages (Barkley et al., 1997; Spira & Fischel, 2007). Additionally, symptoms of H/I are thought to be relatively unstable, as research indicates that they are more prominent in younger children and tend to decrease with age (APA, 2013). Given the young age of the participants in this study and the developmental course of INA and H/I symptoms, it is possible that the results in this study would not generalize to an older sample. It would be interesting to investigate the same research questions in a follow-up study that would include a subsample of this sample at a later developmental stage, or to investigate adult outcomes of this sample. Also, future research could consider investigating these results in comparison with older children.

A substantial amount of research has consistently identified INA as a robust predictor of academic achievement (Merrell et al., 2017; Sayal et al., 2015). However, results from the present study indicated that higher levels of INA did not significantly predict academic achievement after accounting for cognitive abilities. The present study measured INA based on parent- and teacher-rated behaviours and did not use objective measures of INA, which is a limitation in this study, and could potentially explain this finding. Future research could consider including objective measures of INA (e.g., Continuous Performance Task, Visual Search Task, Spatial Conflict Task) to examine the associations between INA and academic achievement. Additionally, while the present study found an association between higher levels of INA and academic underachievement, this association did not persist after accounting for cognitive abilities. Cognitive abilities are known to influence both, academic achievement, as well as INA (Polderman et al., 2010). Despite the known associations between deficits in cognitive abilities and INA, however, the direction of this relationship remains unclear. It would be interesting to investigate whether INA mediates or moderates the relationship between cognitive abilities and academic achievement, or whether cognitive abilities mediate or moderate the relationship between INA and academic achievement.

An additional limitation of this study was the limited number of indicators of academic achievement that were included, which may limit the generalizability of the results to overall academic achievement. Specifically, the objective of this study was to investigate the associations between increasing levels of INA and basic reading, spelling, and math skills, as these basic skills are known to influence the acquisition of more complex skills. For example, decoding skills are known to influence reading comprehension skills (Perfetti, 1992; Samuels, 1994; Stanovich, 2000); basic spelling skills are known to influence writing composition skills (Hayes & Flower, 1980; Juel, 1988; Juel et al., 1986; Scardamalia & Bereiter, 1986); and basic math skills are known to influence math problem-solving skills (Geary & Hoard, 2005). However, it is possible that INA exerts a greater influence on more complex skills than it exerts on basic skills. Basic skills tend to become more automatized with increasing exposure (Geary & Hoard, 2005; National Reading Panel, 2000) and could potentially require fewer attentional skills. Therefore, future research could consider investigating the associations between increasing levels of INA and complex academic skills, such as reading comprehension, writing composition, and math problem solving skills, in addition to basic skills, after accounting for known risk factors. A final limitation to note is that, although the present study accounted for several risk factors known to influence the relationship between INA and academic achievement, certain important risk factors were not included. For example, the presence of an LD or other comorbid MH diagnoses are known to influence academic achievement but were not included in this study. Similarly, background risk factors, such as childhood adversity (e.g., trauma, caregiver neglect, maltreatment, abuse, domestic violence) and physical health conditions are also known to influence academic achievement. Additionally, cognitive variables, such as overall memory abilities or phonological processing skills are known to influence academic achievement but, similarly, were not included in this study. Future research could examine these associations including these known predictors of academic achievement as covariates.

Clinical and Educational Implications

The present study underscores several important implications for the practice of school psychology. Results from the current study indicated that, although INA significantly predicted academic achievement, the association did not persist after accounting for cognitive abilities. This finding highlights the importance and contribution of cognitive factors to academic achievement, which in turn, emphasizes the importance of administering psycho-educational batteries to students demonstrating high levels of INA and/or H/I behaviours and academic difficulties. The early identification of deficits in specific cognitive abilities and impairments in specific academic skills is essential to guiding instruction and interventions. Although cognitive abilities are generally not considered malleable, understanding the challenges a student with specific cognitive deficits experiences is essential to a school psychologist's recommendations. For example, breaking complex tasks into smaller, more manageable steps reduces demands on cognitive load and is helpful to students with working memory deficits. Importantly, although deficits in cognitive abilities have been consistently associated with academic impairments, with the appropriate instructional modifications and classroom supports in place, deficits in cognitive abilities are not deterministic of academic underachievement (Gottfredson, 1997).

Additionally, standardized tests of academic achievement, which are typically included in standard psycho-educational assessments, are thought to accurately identify impairments in specific academic skills (Kaufmann et al., 2012). In contrast, subjective measures of achievement, which rely on classroom performance and teacher-rated progress, are often unable to quantify skills deficits (Langberg et al., 2011). For example, a student who is unable to remain seated or on-task long enough to complete a classroom task will most likely receive low grades. However, a low grade would not necessarily indicate a skills deficit. Similarly, non-disruptive students receiving additional support from teachers and assistance from parents would likely receive satisfactory grades. However, a satisfactory grade would not necessarily indicate the absence of a skills deficit. Early identification of deficits in specific academic skills is essential to guiding appropriate interventions, as undetected skills deficits could potentially be detrimental to a student's academic progress.

Notably, although deficits in academic skills are important factors for school psychologists to consider when determining appropriate interventions and supports, INA and H/I behaviours should be taken into consideration in conjunction with skills deficits. The present study underscores the importance of understanding INA and H/I behaviours at the symptom level rather than the diagnosis level. Specifically, although the entire sample was thought to be experiencing academic difficulties and suspected of ADHD, only half the sample met diagnostic criteria for ADHD. This finding demonstrates that high levels of INA and/or H/I behaviours are not necessarily indicators of ADHD, as students can appear INA or H/I for several reasons other than ADHD. For example, a student could appear distracted or off-task due to lack of sleep or a sleep disorder, due to MH disorders other than ADHD, such MDD, OCD, ASD, or PTSD, or due to an LD when presented with a difficult academic task (Abramovitch et al., 2013; Grzadzinski et al., 2011; Levin et al., 2007; Nitschke et al., 2004; Precenzano et al., 2016; Szymanski et al., 2011). Similarly, a student with an LD demonstrating out of seat behaviours when expected to complete seat work could potentially be attempting to avoid a difficult academic task. In sum, although INA and H/I behaviours are core symptoms of ADHD, they are also characteristic of other conditions or MH disorders, which underscores the importance of identifying the factors underlying the INA or H/I behaviour through differential diagnosis procedures. When school psychologists are confronted with the challenging task of interpreting parent- and teacher-rated INA and H/I behaviours, a differential diagnosis is necessary to determine accurate diagnoses and appropriate interventions. It is the responsibility of the school psychologist to help parents and teachers understand the factors underlying INA and H/I behaviours. Importantly, interventions and supports should be guided by symptoms and factors underlying behaviours, and not be based solely on diagnoses.

Conclusions

The present study indicated that, while increasing levels of INA behaviours were associated with academic underachievement in basic reading, spelling, and math skills, these associations did not persist when cognitive abilities were taken into accounted. This finding highlights the importance of looking beyond observable INA and H/I behaviours to determine the underlying factors influencing academic achievement. Importantly, accurate identification of deficits in specific academic skills and the underlying factors influencing achievement in these skills are essential components in determining appropriate recommendations and targeted interventions. Targeted interventions could, in turn, lead to greater academic success in students with academic difficulties. Given the well-established association between academic underachievement and decreased educational, psychosocial, and functional outcomes across the lifespan, improving a student's academic functioning can potentially lead to subsequent improved life outcomes.

Table 1

Demographic Characteristics of Total Sample (N = 354)

Demographic Characteristics	*N (%)*	*M (SD)*	Minimum	Maximum
Sex				
Male	247 (70%)	-	-	-
Female	107 (30%)	-	-	-
Age	-	8.56 (1.62)	5.42	12.58
Grade	-	2.80 (1.65)	0	7
Parental Education	-	5.95 (1.63)	3	8
Family Structure				
1-Parent Family	72 (20%)	-	-	-
2-Parent Family	282 (80%)	-	-	-
Birthweight	-	7.55 (1.41)	2.25	11.06

Note. Age measured in years. Grade measured in numeric grade level (0 = Grade Primary). Parental Education was used as a univariate proxy measure of SES, and was measured by the highest level of education attained by the parent with the highest education on a scale of 1 to 8 (1 = some elementary; 2 = completed elementary; 3 = some secondary; 4 = completed secondary; 5 = some community or technical college; 6 = completed community or technical college; 7 = some university or teachers college; 8 = completed university or teachers college). Birthweight measured in pounds.

Table 2

Clinical Description of Sample Indicating Number and Percentages of Mental Health Disorders Diagnosed in Sample

	Total Sample *N* = 354	
Mental Health Diagnosis	*N*	%
ADHD Total	184	52
ADHD Presentation		
ADHD-PI	56	16
ADHD-HI	15	4
ADHD-C	113	32
Learning Disability (LD)	186	53
MH Dx other than ADHD and/or LD	103	29
Oppositional Defiant Disorder	21	6
Generalized Anxiety Disorder	20	6
Autism Spectrum Disorder	16	5
Sleep Disorders	15	4
Specific Phobia	10	3
Enuresis	9	3
Tourette’s Disorder	9	3
Chronic Motor Tics	6	2
Stereotypical Movements	5	1
Conduct Disorder	4	1
Obsessions	4	1
Other MH Disorders[a]	19	5
No Diagnosis	37	11

Note. ADHD = Attention-Deficit/Hyperactivity Disorder. ADHD-PI = Attention-Deficit/Hyperactivity Disorder Predominantly Inattentive Presentation. ADHD-HI = Attention-Deficit/Hyperactivity Disorder Hyperactive/Impulsive Presentation. ADHD-C = Attention-Deficit/Hyperactivity Disorder Combined Presentation. LD = Learning Disability. LD includes students considered at-risk for Learning Disability. MH Dx = Mental Health Diagnosis/es.

a. Other MH Disorders = Disorders that were diagnosed in less than 1% (3 or less counts per diagnosis) of the total sample and include diagnoses of Acute Traumatic Stress, Body Dysmorphic Disorder, Chronic Vocal Tics, Compulsions, Dysthymic Disorder, Encopresis, Major Depressive Disorder, Mania/Hypomania, Separation Anxiety Disorder, Social Phobia, Transient Tic Disorder

Table 3

Clinical Description of Total Sample, Indicating Numbers and Percentages of Comorbid Diagnoses

Number of Diagnoses	Diagnoses	Total Sample N = 354	
		N	%
1 Diagnosis n = 170 (48%)	ADHD-only	74	21
	LD-only	70	20
	Other MH Diagnosis [a]	26	7
2 Diagnoses n = 112 (31%)	ADHD + LD	70	20
	ADHD + 1 Additional MH Diagnosis [a]	19	5
	LD + 1 Additional MH Diagnosis	19	5
	2 Other MH Diagnoses	4	1
3 Diagnoses n = 29 (9%)	ADHD + LD + 1 Additional MH Diagnosis	16	5
	ADHD + 2 Additional MH Diagnoses	3	1
	LD + 2 Additional MH Diagnoses	7	2
	3 Other MH Diagnoses	3	1
4 Diagnoses n = 3 (1%)	ADHD + LD + 2 Additional MH Diagnoses	2	1
	LD + 3 Additional MH Diagnoses	1	<1
5-6 Diagnoses n = 3 (1%)	LD + 4 Additional MH Diagnoses	1	<1
	5-6 Other MH Diagnoses	2	1
No Diagnosis		37	11

Note. ADHD = Attention-Deficit/Hyperactivity Disorder. LD = Learning Disability. LD includes students considered at-risk for Learning Disability. MH Diagnosis/es = Mental Health Diagnosis/es.

a. Other/Additional MH Diagnosis/es = Disorders other than ADHD and LD, including Acute Traumatic Stress, Autism Spectrum Disorder, Body Dysmorphic Disorder, Chronic Motor Tics, Chronic Vocal Tics, Compulsions, Conduct Disorder, Dysthymic Disorder, Encopresis, Enuresis, Generalized Anxiety Disorder, Major Depressive Disorder, Mania/Hypomania, Obsessions, Oppositional Defiant Disorder, Separation Anxiety Disorder, Sleep Disorders, Social Phobia, Specific Phobia, Stereotypical Movements, Transient Tic Disorder, Tourette's Disorder.

Table 4

Means, Standard Deviations, and Minimum and Maximum Scores for Inattentive and Hyperactive/Impulsive Symptoms Endorsed on PICS and TTI Based on Parent-Rated (PICS) and Teacher-Rated (TTI) Inattentive and Hyperactive/Impulsive Behaviours

Behavioral Symptoms	*Mean*	*SD*	Minimum Score	Maximum Score
Inattention Total				
(PICS + TTI)	10.23	4.44	0	18
Parent-Rated (PICS)	4.72	2.86	0	9
Teacher-Rated (TTI)	5.52	2.72	0	9
Hyperactivity/Impulsivity				
(PICS + TTI)	8.10	5.20	0	18
Parent-Rated (PICS)	4.41	3.04	0	9
Teacher-Rated (TTI)	3.69	3.14	0	9

Note. PICS = Parent Interview for Child Symptoms (Schachar et al., 2000); TTI = Teacher Telephone Interview (Tannock et al., 2002). Scores range from 0-9 on each measure.

Table 5

Means, Standard Deviations, and Minimum/Maximum Scores for WISC and VMI Indices Presented in Standard Scores (M = 100; SD = 15)

Index	*Mean*	*SD*	Minimum Score	Maximum Score
VCI	96.74	12.89	63	137
POI/PRI/VSI	100.17	14.08	64	136
FDI/WMI	91.32	12.75	56	130
PSI	90.96	13.36	53	128
VMI	92.16	12.24	59	133

Note. WISC = Wechsler Intelligence Scale for Children (Third Edition - WISC-III; Fourth Edition – WISC-IV; Fifth Edition – WISC-V; Wechsler 1991; Wechsler 2003; Wechsler 2014). VCI = Verbal Comprehension Index, WISC-III, WISC-IV, WISC-V; POI = Perceptual Organization Index, WISC-III; PRI = Perceptual Reasoning Index, WISC-IV; VSI = Visual Spatial Index, WISC-V; FDI = Freedoms from Distraction Index, WISC-III; WMI = Working Memory Index, WISC-IV, WISC-V; PSI = Processing Speed Index, WISC-III, WISC-IV, WISC-V; VMI = Visual Motor Integration Index, Beery-Buktenica Developmental Test of Visual-Motor Integration (Fourth Edition – VMI-4; Fifth Edition – VMI-5; Sixth Edition – VMI-6; Beery, 1997; Beery, 2006; Beery & Beery, 2010).

Table 6

Means, Standard Deviations, and Minimum/Maximum Scores of WIAT Subtest Standard Scores (M = 100; SD = 15) as Indicators of Academic Achievement in Reading (Word Reading Subtest), Spelling (Spelling Subtest), and Math (Numerical Operations Subtest)

WIAT Subtest	*Mean*	*SD*	Minimum Score	Maximum Score
Word Reading	93.63	15.92	54	143
Spelling	89.91	13.83	44	131
Numerical Operations	88.06	13.54	40	127

Note. WIAT = Wechsler Individual Achievement Test (Second Edition – WIAT-II; Third Edition-WIAT–III; Wechsler, 2005; Wechsler, 2009). WIAT scores are presented using index composite scores (*M* = 100; *SD* = 15).

Table 7

Hierarchical Multiple Linear Regression Analyses Predicting Academic Achievement in Reading (WIAT Word Reading Subtest), Spelling (WIAT Spelling Subtest), and Mathematics (WIAT Numerical Operations Subtest) from Background Risk Factors, Cognitive Variables, and Total Symptom Count of Parent- and Teacher-Rated Inattention and Hyperactivity/Impulsivity

	Domain of Academic Achievement					
	Reading		Spelling		Mathematics	
Predictor	ΔR^2	β	ΔR^2	β	ΔR^2	β
Step 1						
Background Risk Factors	.03*		.02		.09***	
Sex		.12*		-.04		.12*
Age		-.06		-.14*		-.21***
Birthweight		.06		.03		.03
SES		.07		-.03		.13*
Family Structure		-.03		.00		-.05
Step 2						
Cognitive Variables	.35***		.28***		.31***	
VCI		.36***		.24***		.20***
VSI		-.07		-.03		.14*
WMI		.29***		.31***		.21***
PSI		.09		.03		.13**
VMI		.12*		.17**		.12*
Step 3						
Behavioural Variables	.007		.003		.02*	
INA-Total		-.04		-.02		-.002
HI-Total		.11*		.07		-.13**
Total R^2	.38***		.30***		.41***	
n	354		354		354	

Note. WIAT = Wechsler Individual Achievement Test (Second Edition – WIAT-II; Third Edition-WIAT–III; Wechsler, 2005; Wechsler, 2009; M = 100; SD = 15). Background Risk Factors: Sex was coded as 0 = Female, 1 = Male; Age was measured in months; Birthweight was measured in ounces; SES: Parent Educational Attainment was used as a univariate proxy measure of SES, where the highest level of education of the parent with the highest level of education was coded on a scale of 1 to 8 (1 = some elementary; 8 = completed university or teachers college); Family Structure was coded as 0 = 2-parent family, 1 = 1-parent family. Cognitive variables: VCI = Verbal Comprehension Index on Wechsler Intelligence Scale for Children (Third Edition - WISC-III; Fourth Edition – WISC-IV; Fifth Edition – WISC-V; Wechsler 1991; Wechsler 2003; Wechsler 2014); VSI = Visual Spatial Index, WISC-V (VSI includes Perceptual Organization Index, WISC-III, and Perceptual Reasoning Index, WISC-IV); WMI = Working Memory Index, WISC-IV, WISC-V (WMI includes Freedom from Distraction Index, WISC-III); PSI = Processing Speed Index, WISC-III, WISC-IV, WISC-V; VMI = Visual Motor Integration Index, Beery-Buktenica Developmental Test of Visual-Motor Integration (Fourth Edition – VMI-4; Fifth Edition – VMI-5; Sixth Edition – VMI-6; Beery, 1997; Beery, 2006; Beery & Beery, 2010). WISC and VMI scores are presented using index composite scores (M = 100; SD = 15). Behavioural Variables: INA-Total = Total symptom count of parent- and teacher-rated inattention; HI-Total = Total symptom count of parent- and teacher-rated hyperactivity/impulsivity.

* $p < .05$ ** $p < .01$ *** $p < .001$.

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