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Exploring Cognitive Profiles of Children With Learning Difficulties

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by

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Abstract

This study compares the role of cognitive processes in children diagnosed with learning disabilities (LD) through the traditional aptitude-achievement discrepancy model with students diagnosed on the basis of their low achievement alone. Historically, in North American settings, LD has been diagnosed when an individual's achievement on standardized tests in reading, mathematics, or written expression is substantially lower than the expected level for age, schooling, and level of intelligence (American Psychiatric Association, 2000). As this conceptualization has come under increasing scrutiny, alternate identification methods such as the low achievement/non-discrepant method have been gaining support in the literature (e.g. Siegel, 1999; Stanovich, 2005). A secondary objective of this study is to determine whether identifiable differences exist between the cognitive profiles (WISC-IV) of students diagnosed with reading disability (RD) and mathematics disability (MD). This study also addresses whether the WISC-IV Working Memory Index can be used to differentiate between various categories of students with LD. The findings of this study indicate that the discrepant (DLD) and non-discrepant (NDLD) learning disability (LD) groups could not be distinguished by the WISC-IV Working Memory Index (WMI). Amongst the overall sample of students with LD, those with average or above working memory scores (high) could be differentiated from those with below average working memory scores (low) on the WISC-IV Perceptual

Reasoning Index (PRI). Students with LD who had low WMI scores could also be differentiated from those with high WMI scores on four WIAT-II subtests. WMI scores could not be used to differentiate students with Reading Disability (RD), Mathematics Disability (MD) or Generalized Learning Disability (GLD). However, differences between these three LD groups were found on the WISC-IV Verbal Comprehension Index (VCI), Perceptual Reasoning Index (PRI), and marginally on the Processing Speed Index (PSI). Finally, the four WISC-IV Index scores were able to correctly predict group membership in the RD, MD, and GLD groups approximately 70% of the time.

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CHAPTER I

Introduction

The primary purpose of this investigation is to compare the cognitive profiles of students diagnosed with different forms of learning disabilities (LD). Specifically, profiles of students with reading disabilities (RD) and mathematics disability (MD) will be compared on WISC-IV and WIAT-II measures. Special emphasis will be placed on the role of working memory (WM) and whether or not WISC-IV WM measures can be used to differentiate between those who meet the "traditional" discrepancy based criteria for LD and those whose diagnoses rely on their low achievement alone. The investigation will also examine if there are differences in WM in students with RD and MD.

Learning disabilities (LD) have historically been diagnosed when achievement on standardized tests in reading, mathematics, or written expression is substantially lower than expected for age, schooling, and level of intelligence (American Psychiatric Association, 2000). As this conceptualization has come under increasing scrutiny, alternate identification methods such as the low achievement/non-discrepant method (e.g. Joshi, 2003; Siegel, 1999; Stanovich, 1999, 2005; Sternberg & Grigorenko, 2002) and the response to intervention (RTI) method (e.g. Machek & Nelson, 2007) have been gaining support in the literature.

Given the uncertainty surrounding LD in terms of what it actually is and who qualifies for the disorder, the question of how generalizable research findings are can be directly attributed to the wide array of theoretical underpinnings represented in the literature (Meyer, 2000). In an analysis of Canadian LD studies, Klassen (2002) pointed out that students identified with LD in one study might not necessarily meet the criteria for LD in another study as samples in each study could represent different populations. The possibility that each sample group in a series of studies might represent different populations is cause for concern as it becomes difficult to draw conclusions on any given characteristic of LD outside of the population from which the sample was drawn.

A few studies have examined this issue in some depth. Brackett and McPherson (1996) used four different discrepancy models in addition to their own proposed model to interpret results from the Wide Range Achievement Test-Revised (WRAT-R) and the Wechsler Intelligence Scale for Adults-Revised (WAIS-R). Little agreement was found between any of the models with a range of 43% agreement to 86% agreement reported between them. Similarly, Proctor and Prevatt (2003) compared the level of agreement among four discrepancy models and concluded that although each model diagnosed similar numbers of students, different students were being diagnosed under each model. The authors subsequently called for additional research to further discern the consequences of selecting different models for diagnosing LD. Proctor and Prevatt (1993) similarly noted that more research is needed to discern the consequences of diagnosing LD with different eligibility models as different models may identify dissimilar samples of students with LD.

The role of working memory (WM) in LD students is of particular interest in this investigation as it appears to be linked to LD. For example, Danemen (2001) reported that students whose IQ scores fell within the average range and below the 25th percentile on standardized tests of reading and mathematics had a range of deficits on WM tasks when compared to their non-disabled counterparts. While WM deficits have been widely noted in samples of LD students, the degree to which WM constrains learning in children identified with LD is not clearly understood (Gathercole et al., 2006; Meyer, 2000).

Definitions

I will now briefly highlight and conceptually define some of the key terms that appear in the body of this study. A detailed discussion follows in literature review.

Conceptual Definition of Discrepancy-Based Learning Disabilities

This investigation examines whether students who meet the criteria for discrepancy-based LD (DLD) can be differentiated from students whose diagnosis relies on their low achievement alone. The two groups are compared on the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV) Working Memory Index (WMI). For this investigation, students in the DLD group have been categorized according to the American Psychiatric Association's (2000) Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR) guidelines (See Appendix A). The DSM-IV-TR states that LD is diagnosed when an "individual's achievement…is substantially below" the expected level for age, schooling, and intelligence (American Psychiatric Association, 2000). According to this conceptualization, LD refers to a number of disorders that may affect the acquisition, retention, organization, understanding or ability to use verbal or nonverbal information and occurs in individuals who demonstrate, at a minimum, average thinking and reasoning abilities (Learning Disabilities Association of Canada, 2007, LD Defined Section).

Although there are several discrepancy models, the standard score comparison model, also known as the simple discrepancy model, is the most widely used model in practice (e.g. Mercer, Jordan, Allsopp, & Mercer, 1996) and was used to categorize the students in this study. This method involves a direct comparison between IQ and standardized achievement scores. The DSM-IV-TR states that a pre-established criterion of two standard deviations between achievement and ability is typically required for an LD diagnosis meaning that a child's achievement scores must be at least 30 points below his or her IQ in order to qualify as having LD (American Psychiatric Association, 2000; Mellard et al., 2004; Proctor & Prevatt, 2003). Although the amount of discrepancy required for diagnosis is typically two standard deviations, a discrepancy between one and two standard deviations may be used if IQ performance is compromised by a general medical condition, an associated disorder in cognitive processing, a comorbid mental disorder, or an individual's cultural or ethnic background (American Psychiatric Association, 2000). Based on the DLD conceptualization, all students in the DLD sample group present with the minimum 30 point discrepancy between cognitive scores and reading and/or mathematics achievement scores. From a discrepancy-based standpoint, the students in this sample are all performing far below what would be expected in terms of reading and/or mathematics given their level of intelligence.

Conceptual Definition of Low Achievement/Non-Discrepant Learning Disabilities

Although a part of many recognized LD definitions (e.g. Learning Disabilities Association of Canada, 2002, LD Defined Section; APA, 2000), the appropriateness of the discrepancy method has been aggressively challenged by many leading researchers in the field (e.g. Siegel, 1989; Stanovich, 2005; Sternberg and Grigorenko, 2002). Authors such as Siegel (1989) and Stanovich (2005) have been calling for an overhaul in LD identification methods and have advocated for the widespread adoption of a non-discrepant identification method. In the current study, low achievement or non-discrepant LD (NDLD) refers to students who score below the 25^{th} percentile on standardized measures of reading or mathematics. This would normally include students who score below the 25^{th} percentile in standardized measures of writing, however, a writing measure was not included in the database that was made available to the researcher. According to proponents of the non-discrepant method, IQ is irrelevant for reasons explained in the following literature review. Other researchers maintain that a cutoff point of 80 should be used for IQ to rule out mental retardation. The conceptualization of NDLD mirrors that of Swanson and Siegel’s (2001) definition: Students in the NDLD sample scored below the 25^{th} percentile in mathematics and/or in reading with an IQ score of at least 80 to rule out mental retardation. Thus, the students in the NDLD group are considered to be displaying low achievement in reading or mathematics without the traditional discrepancy. Under some provincial funding models in Canada, these students would not typically qualify for specialized services.

Conceptualization of Working Memory

Generally speaking, memory can be thought of as a series of separate and distinct subsystems essential for learning. These subsystems include but are not limited to short-term memory (SMT), long-term memory (LTM), and WM. WM as a construct was chosen for this investigation because it is a core component of the WISC-IV and a learning process that is thought to be impaired in persons with LD (e.g. Chiappe, Hasher, & Siegel, 2000; De Jong, 1998; Palmer, 2000; Siegel & Ryan, 1989; Swanson & Siegel, 2001). Broadly defined, WM is a system of limited storage capacity involved in preserving information while simultaneously processing the same or other information (Baddeley, 1986; Miyake, 2001; Swanson, 2006). Simply put, WM refers to the ability to hold pieces of information while simultaneously processing other pieces of information until a complete thought or concept is formed. The WM measure in the current investigation is from the WISC-IV called the Working Memory Index (WMI), which is made up of the Digit Span and Letter-Number-Sequencing subtests.

Rationale of the Study

The current investigation aims to (a) examine whether the WISC-IV WMI can be used to differentiate DLD from students with NDLD; (b) to investigate the role that the WISC-IV WMI has in differentiating different subtypes of LD; (c) and to examine if there are overall differences in WISC-IV cognitive profiles of students diagnosed with different forms of LD.

Addressing Identification Issues and Methodological Concerns

Are there underlying cognitive differences between students with DLD and NDLD ? This is one of the most pressing questions in the LD field that has yet to be resolved (e.g. D'Angiulli & Siegel, 2003; Keogh, 2005; Proctor & Prevatt, 2003; Stanovich, 2005). According to some authors, the answer is a resounding no (e.g. Fletcher et al., 1994; Stanovich & Siegel, 1994; Stanovich, 2005). Stanovich (2005) and Fletcher et al. (1994) argue there is little evidence of underlying processing differences between these two groups of students. Using reading disabilities (RD) as an example, Stanovich and Siegel (1994) found no significant differences between discrepant and non-discrepant readers on measures of word recognition, orthographic, or phonological skills.

But to others, the answer is less than certain (e.g. Meyer, 2000). For instance, Wolf (1997) found differences in orthographic memory, naming speed, and phonological awareness in different groupings of students with LD. Given these inconsistencies, the evidence is at best inconclusive and more research is needed in this area (Meyer, 2000). A key reason for comparing data sets of students with DLD and NLD is to therefore gain a clearer understanding of the implications of identifying students through different criteria. Important because, as D'Angiulli and Siegel (2003) pointed out, LD identification/definitional issues are having an adverse affect on the methodological soundness of much of the current research.

The Role of the WISC-IV Working Memory Index in Differentiating Learning Disability Groups

The literature has consistently stated WM is deficient in students with LD when compared to typically achieving students (e.g. Chiappe, Hasher, & Siegel, 1999; De Jong, 1998; Gathercole et al., 2006; Cohen-Mimran & Sapir, 2007; Palmer, 2000; Siegel & Ryan, 1989; Swanson, 2000; Swanson & Siegel, 2001). In relation to LD, WM deficits have been linked to poor reading performance (e.g. Cohen-Mimran & Sapir, 2007; Holsgrove & Garton, 2006; Howe et al., 1999; Swanson and Siegel, 2001), mathematical disabilities (e.g. Bull & Johnston, 1997; Mabbott & Bisanz, 2008; Swanson, 1993), and have even been shown to affect everyday life tasks that extend beyond reading and math (McNamara & Wong, 2003). Gathercole et al. (2006) found that WM skills were significantly related to the severity of LD in both reading and mathematics in a sample of children with RD. Similarly, Henry (2001) found that when compared to children with average abilities, those with more severe LDs had greater WM impairments. However, to the best of this investigators knowledge, the literature does not address whether there are differences in WM between students diagnosed with DLD and students diagnosed with NDLD. This uncertainty will be addressed in both the literature review and in the actual study itself.

Differentiating Learning Disability Groups on the Basis of Cognitive Processes

In addition to examining WM scores in samples of students with DLD and NDLD, this study also investigates whether students with reading disability (RD) and mathematics disability (MD) can be differentiated on other WISC-IV Index scores. Although cognitive differences between RD and MD have been widely investigated, to the best of this investigator's knowledge, the question has not been addressed using WISC-IV measures. The reason for this may be because the WISC-IV is a relatively new cognitive measure and researchers may simply not yet have sufficient data. Previous studies have suggested that several cognitive processes may be related to RD and MD. For example, research pertaining to disabilities in mathematics has focused on phonological and working memory, storage/retrieval from long-term memory, as well as visual processing abilities (Floyd, Evans, & McGrew, 2003).

A study by Davis, Parr, and Lan (1997) examined the characteristics of LD in reading, spelling, and arithmetic via the Revised Woodcock-Johnson Psychoeducational Battery. The authors found that students with MD had weaker non-verbal skills than students with reading and spelling deficits. The students with both reading and spelling deficits had stronger nonverbal skills. Cain and Oakhill (2006) reported that there does not appear to be a single underlying source of poor comprehension, as weak verbal and cognitive skills appear to influence the reading development of poor comprehenders in several ways.

Nevertheless the primary cognitive mechanisms that separate MDs from RDs remain unclear (e.g. Swanson & Jerman, 2006).

Rationale Summary

This study compares the role of cognitive processes in children diagnosed with learning disabilities (LD) through the traditional aptitude-achievement discrepancy model with students diagnosed on the basis of their low achievement alone. This study also examines whether identifiable differences exist between the cognitive profiles (WISC-IV) of students diagnosed with reading disability (RD) and mathematics disability (MD). This study also addresses whether the WISC-IV Working Memory Index can be used to differentiate between various categories of LD students. Specifically, the current investigation aims to (a) examine whether the WISC-IV WMI can be used to differentiate DLD from students with NDLD; (b) to investigate the role that the WISC-IV WMI has in differentiating different subtypes of LD; (c) and to examine if there are overall differences in WISC-IV cognitive profiles of students diagnosed with different forms of LD.

The importance of gathering data with regards to these objectives is straightforward. First, more research is needed to help sort out methodological concerns surrounding the discrepant/non-discrepant LD controversy. Second, although WM has been linked to LD, its usefulness in differentiating between LD groups has been lacking in the literature. Third, the primary cognitive mechanisms that separate MDs from RDs remain unclear (Swanson, & Jerman, 2004). Moreover, as Mayes and Calhoun (2007) pointed out, little has been published on WISC-IV correlates of academic achievement.

CHAPTER II

Literature Review

The LD field is currently in a state of flux and has been for some time, as even some of the most fundamental questions about the disorder remain shrouded in uncertainty. Questions such as how to best theoretically conceptualize the disorder, how to best operationally define the disorder, and what cognitive processes are responsible for the disorder all remain unanswered. This investigation will address some of these issues. To put these issues into context, I first explain how history has helped shape current trends and research within the field, followed by a review of the development of the LD field in Canada and in the United states. Some of the most prominent theoretical and operational definitions of LD are discussed as well as the controversies that surround these definitions.

Part One: Learning Disabilities in Historical Context-From Past to Present Day

The emergence of key issues such as the discrepancy question can be traced back to distinct eras or time periods, each characterized by specific interests of researchers, prominent theories, and leading tools of the field. Hallahan and Mercer (2002) summarized these eras as the European Foundation Period (approx. 1800-1920), the U.S. Foundational Period (approx. 1920-1960), the Emergent Period (approx. 1960-1975), the Solidification Period (approx. 1975-1985), and the Turbulent Period (approx. 1985-Present Day).

According to Hallahan and Mercer (2002), the European Foundational Period was a time when researchers and physicians from Europe began exploring the relationship between brain injury and disorders of spoken language. This was followed by the second era, what is now known as the U.S. Foundational Period. During this era, American researchers focused their interests on the remediation of learning difficulties experienced by children in schools (Hallahan & Mock, 2003). The development of tools and methods of instruction characterized the third era, the Emergent Period. This era saw greater public and professional awareness of LD as both parents and teachers became increasingly familiar with the disorder. It was during the Emergent Period that a great deal of effort was put into the development of comprehensive definitions as well as effective programming for students with LD (Hallahan & Mock, 2003). Following the Emergent Period was a time of relative calm. Hallanhan and Mercer (2002) called this the Solidification Period. During the Solidification Period, an influx of empirically validated research occurred resulting in the emergence of federal regulations and definitions.

The latter part of the 20th century to present day has been characterized by considerable uncertainty in the field. Accordingly, Hallahan and Mercer (2002) labeled this the Turbulent Period. With the number of identifiable LD cases on the rise, issues that did not receive much attention previously were now at the forefront of both the public and educators' collective awareness. As a result, both government and professional organizations have sought and proposed numerous definitions with hopes of arriving at some sort of consensus and general understanding of the disorder.

Thinking About Learning Disabilities: Canadian and International Theoretical and Operational Perspectives

In Canada, some provincial authorities, including Alberta Education, have adopted guidelines published by the Learning Disabilities Association of Canada (LDAC) (Klassen, 2002). Within the United States, the federally mandated Individuals with Disabilities Education Act (IDEA 97/04) has become the procedural safeguard for students with LD. Some of the most relevant theoretical conceptualizations of LD in both Canada and the United States are discussed below (See Appendixes A through D for complete definitions).

Conceptual Perspectives of Learning Disabilities in Canada

In 2002, The Learning Disabilities Association of Canada (LDAC) adopted a definition of LD that characterizes it as "a number of disorders which may affect the acquisition, organization, retention, understanding or use of verbal or nonverbal information. These disorders affect learning in individuals who otherwise demonstrate at least average abilities essential for thinking and/or reasoning. As such, learning disabilities are thought to be distinct from global intellectual deficiency. Learning disabilities result from impairments in one or more processes related to perceiving, thinking, remembering or learning." Several provincial educational departments including The Provincial Government of Alberta (Alberta Education) have also officially endorsed this definition (see Appendix D), as stated in the Alberta Education Special Education Definition (2004/2005) manual (Alberta Education, 2004).

Klassen (2002) reported that as of the year 2000, eight out of ten Canadian provinces defined LD using traditional discrepant approaches, which include the IQ-achievement discrepancy method. More recently, Kozey and Siegel (2008) reported that several Canadian provinces have adopted the official definition of LD as outlined by the LDAC either in part or in its entirety. The LDAC characterizes LD as “disorders (that) affect learning in individuals who otherwise demonstrate at least average abilities” required for thinking or reasoning (Learning Disabilities Association of Canada, 2007, LD Defined Section).

According to Kozey and Siegel (2008), the Canadian provincial education departments of British Columbia, Alberta, New Brunswick, and Newfoundland and Labrador have adopted the LDAC definition in its entirety. Saskatchewan and Nova Scotia have included significant portions of the definition. Ontario, Prince Edward Island, along with the Yukon and Northwest Territories are reportedly supportive of the LDAC definition, but do not have any formal documents that specifically align with the definition.

With regards to the role that intelligence plays in provincial definitions, half of the provinces require at least average intelligence for an official diagnoses of LD but none of the provinces specify what constitutes average intelligence. In terms of a discrepancy requirement, British Columbia requires at least average intellectual ability with a minimum of one standard deviation below average on achievement tests. Other provinces that refer to a discrepancy as a key feature of the disorder include Alberta, Manitoba, New Brunswick, Nova Scotia, and Newfoundland and Labrador. None of these provinces explicitly state the magnitude of the discrepancy. The only province to reject the discrepancy method outright is Saskatchewan. Finally, Quebec and Prince Edward Island have adopted a non-categorical approach to diagnosing LD (Kozey & Siegel, 2008). A non-categorical approach does not focus on whether or not a child meets a certain criteria. Instead, the focus is placed on the child's deficits and what they are unable to do. The services and resources school jurisdictions are willing to commit to students with LD are often contingent upon pre-specified provincial eligibility criteria. Complicating matters, these criteria tend to differ from province to province making it possible for a child to meet the diagnostic criteria in one province but not in another (Klassen, 2002; Proctor & Prevatt, 2003).

Conceptual Perspectives of Learning Disabilities in the United States and Australia

In the United States, the federal government mandates national standards for both special and regular education. However, it is the individual state departments of education that are responsible for the identification and placement of special needs students within the given federal parameters. Most states subscribe to a discrepancy formula (one to two standard deviations between IQ and achievement) that parallels or is similar to DSM-IV-TR criteria (Oakland et al., 2007).

After P.L. 94-142 (Education of all Handicapped Children Act of 1975) became law in the United States, the federal government published guidelines for identifying students with LD. These guidelines stated that a severe discrepancy between IQ and achievement must exist before a diagnosis of LD can be made.

Legislation entitled the Individuals with Disabilities Act (IDEA 97) was the first major revision to P.L 94-142 in more than 23 years. This piece of legislation was designed to protect the basic rights of individuals with disabilities and to ensure free, appropriate public education for all children with disabilities, including children suspended from school. It has since served as the procedural safeguard of rights for children and families affected by LD. IDEA 97 included provisions that ensure children have meaningful access to the general curriculum through improvements to the IEP; that children with disabilities are included in general education; that reform efforts are related to accountability and high expectation; and that there is a focus on improved teaching and learning. IDEA 97 does not make any reference to psychological processes but requires a "severe discrepancy" between achievement and intellectual ability in one or more of the following: oral expression, written expression, listening comprehension, mathematics calculation, mathematics reasoning, basic reading skill, or reading comprehension (see Appendix C).

In 2004, a new law entitled IDEA 04 was passed in the United States as an amendment to IDEA 97. IDEA 04 provides a conceptualization of LD that maintains key elements found in IDEA 97 but does not include the provision requiring a severe discrepancy between intellectual ability and achievement. Under IDEA 97, a child could not be identified as having LD without an IQ-achievement discrepancy. IDEA 04 requires that both a team of professionals and the child's parents make the LD diagnosis. Although not entirely eliminated, this piece of legislations places less emphasis on discrepancy analysis as a means of identifying LD (NCLD, 2009). IDEA 2004 characterizes a LD as not achieving adequately given the child's age or not meeting grade-level standards in one or more of the following areas: listening comprehension, oral expression, written expression, reading fluency, basic reading skills, reading comprehension, mathematics calculation, or mathematics problem solving. Furthermore, IDEA 2004 states that an LD cannot be the result of cultural factors, limited English proficiency, environmental or economic factors, a visual, hearing, or motor disability; mental retardation; or an emotional disturbance.

In other countries, Australia for example, LD as a diagnostic category has much less relevance (Graham & Bailey, 2007). Unlike the United States, there are no diagnostic categories of LD for funding purposes. Despite having a nationally recognized definition of LD in Australia, its ambiguity has resulted in a wide range of students who are eligible for services. The Australian Senate published a report in 2002, entitled “The Education of Students with Disabilities (Senate Employment, Workplace Relations and Education References Committee, 2002) and adopted a comprehensive definition of LD. According to this report, LD refers to “a disorder in one or more of the basic processes involved in using spoken or written language and may become manifested in a child’s problems” with reading, writing, speaking, listening, spelling, speaking, or mathematical calculation. Specialized assessment for LD is provided by a wide array of school personnel (e.g. psychologists, speech pathologists, reading specialists) for at-risk children who do not respond to early intervention and to students who are identified through group administered achievement tests (Graham & Bailey, 2007).

In many ways, the history, definitions, and research pertaining to LD has paralleled that which has occurred in the United States (Klassen, 2002). As in the United States, students with LD in Canada have been historically characterized by deficits in school achievement despite the absence of mental retardation and instructional shortcomings (Passolunghi & Siegel, 2004). Despite the similarities, Klassen (2002) identified two key legislative differences between the two countries. First, within Canada there is little federal involvement in educational issues as they fall under the direction of provincial jurisdictions. Second, unlike the United States, Canada has no federally mandated law guaranteeing access to special education services. As Klassen pointed out, Canada simultaneously offers less protection to individuals in need of special education services, but allows greater flexibility in terms of implementing theoretical shifts.

The Operationalization of Learning Disabilities: Putting Theory into Practice

Operationally defining something involves making a conceptual definition more precise. For clinicians, the two prominent operational definitions of LD are found in The Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision (DSM-IV-TR) (American Psychiatric Association) and the International Classification of Diseases, 10th Revision (ICD-10) (World Health Organization, 2007). Overall, efforts to operationalize LD have been shrouded with considerable controversy (Hammill, 1993).

DSM-IV-TR. The DMS-IV-TR is one of the most widely relied upon sources of information about mental disorders (including LD) and is used primarily by those in medical or mental health care professions. The DSM-IV-TR identifies four main areas of LD: Reading Disorder, Mathematics Disorder, Disorders of Written Expression, and Learning Disorders Not Otherwise Specified. One of the main diagnostic requirements is that ability in any of these areas (reading, mathematics, written expression), as measured by a standardized test, is substantially below the individual's measured intelligence, chronological age, and age-appropriate education (see Appendix A).

ICD-10. Another medical perspective on LD is the World Health Organization's International Classification of Diseases, Tenth Edition (ICD-10). The ICD-10 provides diagnostic criteria for specific reading disorder, specific spelling disorder, specific disorder of arithmetical skills, mixed disorder of scholastic skills, other developmental disorders of scholastic skills, and developmental disorder of scholastic skills, unspecified. The main feature of these disorders is impairment in the development of specific skills that is not solely accounted for by mental age or inadequate schooling (see Appendix B). For example, a specific reading disorder as described by the ICD-10, may be characterized by reading comprehension, word recognition, and oral reading difficulties (World Health Organization, 2007).

In summary, most theoretical and operational definitions of LD still include a discrepancy requirement. Although IDEA 04 does not entirely remove the discrepancy notion, it certainly places less emphasis on it than other conceptualizations. As far as similarities between the noted definitions, the discrepancy requirement is perhaps the most obvious linking factor. In Canada, there are no federally mandated operational or conceptual definitions of LD. Provincial authorities and school boards have the flexibility to broadly interpret and define LD. As Klassen (2002) reported, between 1989-1999, the definitions of LD used in studies in four Canadian journals varied considerably, with no particular definition taking significant prominence. As such, individual school boards subscribe to their own criteria that tend to differ from one school jurisdiction to another. Given the vast definitional variation in prominent policy documents, it is no wonder that there is so much definitional variation in the literature.

Current State of Affairs

Although progress has been made in the LD field, particularly in the latter part of the 20th century, research conducted during this time also brought to the forefront of our collective attention several challenges within the field. Current literature reveals little continuity or consensus on how to define LD, or for that matter, who exactly qualifies for the disorder. This, in part, has led to the vast array of tests, procedures, and criteria that are currently being used to identify LD, none of which have been officially endorsed by the psychological community or have been established as standard practice. Given this uncertainty, it is not surprising that pinpointing and agreeing upon the underlying processes responsible for learning deficits has been such an arduous task. Complicating matters further, political advocacy groups and legislative bodies have had considerable influence on how LD is defined and, in some cases, have placed limitations on identification practices without always considering current research (Keogh, 2005).

The most current and widely held view characterizes LD as a heterogeneous disorder that is used to describe a wide range of learning difficulties (APA, 2000). In the literature, the term is used to describe both low achievement (regardless of IQ) and underachievement (IQ discrepant) in reading, math, or in overall academics. However, much of the LD research is unclear as to which population is being represented. The assortment of disorders and sub-disorders referred to as LD makes the proper identification of students and interpretation of research a very arduous task (Keogh, 2005; Meyer, 2000).

The Discrepancy Method

Perhaps the most current and controversial issue facing the LD field is the appropriateness of the IQ-achievement discrepancy model. A growing voice of experts has been calling for the abandonment of this method of identification (e.g. Joshi, 2003; Siegel, 1999; Stanovich, 1999, 2005; Sternberg & Grigorenko, 2002). As such, a number of alternative conceptualizations are being pursued in lieu of traditional methods (Mellard et. al, 2004). Some of these approaches include identification based on responsiveness to intervention, non-categorical or low achievement based identification, and identification based on psychological processes (Klassen, Neufeld, & Munro, 2005). The overall hope is that detailed investigations of these processes will eventually lead to a way of directly diagnosing LD (Torgesen, 2001).

Discrepancy Models. Another cause for concern is that most LD definitions endorse the discrepancy method do not specify how the discrepancy should be calculated. Because of this, a variety of aptitude-achievement models are being used in both research and in practice. Moreover, inconsistent sampling itself has made the comparison of results across LD studies considerably challenging (Chapman, 1988; Klassen, 2002).

Three discrepancy models are featured prominently in the literature. These are the grade-level discrepancy method, the standard score discrepancy method, and the regression discrepancy method (APA, 2000; Mellard et al. 2004; Proctor & Prevatt, 2003). A grade level discrepancy is calculated by subtracting a child's actual grade level from his or her expected grade level. This model considers the difference between a child's grade placement and his or her grade-equivalent achievement scores. If the discrepancy exceeds a pre-established criterion (e.g. two grade levels) the child is said to have LD (Proctor & Prevatt, 2003).

The standard score comparison model, also known as the simple discrepancy method, involves a direct comparison between IQ and achievement scores. Unlike the grade-level discrepancy model (which uses grade level as a measure of ability), the standard score comparison model uses IQ scores to represent cognitive ability level and a standardized achievement test scores to represent academic ability level. A pre-established criterion of typically 15 to 30 points or one to two standard deviations between cognitive ability and achievement would constitute an LD, assuming the child has had no historical background of impeded education (Mellard et al., 2004; Proctor & Prevatt, 2003).

Lastly, regression based models examine the difference between IQ and achievement but control for the correlation between the IQ and achievement tests (Proctor and Prevatt, 2003). In regression models, measurement errors associated with achievement and IQ are accounted for. The idea behind regression-based discrepancy models is that when two variables are not correlated perfectly, they begin to regress toward the mean. Due to the imperfect correlation between IQ and achievement, persons with above average cognitive abilities tend to score somewhat lower on achievement tests resulting in expected discrepancies that should be considered typical (Van den Broeck, 2002). Similarly, individuals with below average cognitive ability scores, tend to score somewhat higher on achievement tests, which may result in an underestimation of actual discrepancies. To avoid both the over-identification and under-identification of LD, Thorndike (1963) proposed a regression-based formula that accounts for the less than perfect correlation between IQ and achievement.

Concerns About the Discrepancy Method

Klassen (2002) reported that the majority of theoretical papers published in Canada in the last decade were critical of current LD definitions and proposed new ways of identifying LD. Although the majority of LD definitions are based on some variation of the aptitude-achievement discrepancy model, there appears to be little converging evidence to support this method. According to Torgesen (2001), the discrepancy method was developed as a “fall-back” procedure resulting from a lack of consensus on what the underlying processes responsible for LD are. Researchers such as Siegel (1999) and Stanovich (2005) have long criticized this approach on the basis of its scientific and technical shortcomings and have gone as far as labeling current identification practices as "pseudoscience."

There are several reasons for this level of criticism. First, in RD studies for example, there is little evidence that discrepant poor readers differ from non-discrepant poor readers in terms of cognitive functioning, prognosis, nature of difficulties, or sensitivity to intervention (Hallahan & Mercer, 2002; Stanovich, 2005). Another argument is that certain paper-and-pencil IQ tests do not truly represent intelligence or potential (e.g. Gardner, 1999; Proctor & Prevatt, 2003; Siegel 1989). It has also been argued that the difference scores between intelligence and achievement are unreliable and that simple discrepancy models do not account for the effects of regression toward the mean (Stanovich, 1999).

Sternberg and Grigorenko (2001; 2002) are also highly critical of the discrepancy method and provide several arguments in favor of abandoning the practice. The authors question the assumption that current intelligence tests truly measure all or even most of what intelligence is supposed to be, citing Gardner's (1983) theory of multiple intelligences as a plausible alternate conceptualization. The authors also argue that IQ is confounded with reading and verbal skills. According to Sternberg and Grigorenko, when reading scores are subtracted from IQ scores, the results are invalidated because verbal comprehension skills are being subtracted from itself. Even nonverbal tests are problematic for the authors because they tend to represent less of what intelligence is supposed to be and often require verbal or written directions that some individuals do not fully understand.

Another argument against the discrepancy method is that difference scores are not equivalent at different points on the IQ spectrum (Sternberg and Grigorenko, 2001; 2002). For instance, a difference of 25 points between reading achievement and IQ does not mean the same thing when one's IQ is 80 or 140, even though both sets of scores could be interpreted as a RD. Furthermore, the authors point out that there are multiple forms of RD and that simple difference scores tend to distract from this.

Some authors argue that the Matthew effect may be responsible for an overestimation of IQ scores in good readers and an underestimation of scores in poor readers (Hallahan & Mercer, 2002; Sternberg & Grigorenko, 1999). Matthew effects are a phenomenon described by Stanovich (1986) where good learners get better and poor learners get weaker in skill level. This is often the case in reading acquisition where more advanced skills rely heavily on skills that were learned earlier. Without a solid foundation in basic reading skills, acquiring and mastering advanced skills is less likely (Sternberg & Grigorenko, 1999).

In terms of identification, the question of who is included in an LD sample is a function of what criteria, procedures, and measures are being subscribed to (Keogh, 2005). In relation to which psychometric tests, what cutoff point should be used, and how large a discrepancy ought to be, Keogh (2005) sums up the confusion with this clever analogy: "As fishermen have long known, the size of the net affects the size of the fish that are netted."

Part Two: Learning Disability Subtypes and Processes Linked to the Disorder

Part Two of the literature review examines two major LD subtypes: Reading Disability (RD) and Mathematics Disability (MD). Some of the cognitive processes linked to LD in general and specific to the RD and MD subtypes are also addressed. Finally, special focus is placed on one particular cognitive process linked to LD: The role of WM in students with LD.

Cognitive Processes Related to Reading Disabilities

The primary goal of reading instruction is to teach students to independently recognize text and understand what is being read. For this to occur, the reader must first be able to identify individual words with accuracy and fluency, and secondly, have some general language comprehension skills (Torgesen, 2002). As a child's ability to recognize words with accuracy and fluency improves, his or her sight word vocabulary should also typically improve. It is the development of accurate phonemic decoding skills at an early age that plays an important role in helping children acquire the specific memories for words that require automatic recognition (Torgesen, 2002). For children who are experiencing reading difficulties, an early and ongoing problem in the acquisition of fluent word identification skills is often involved.

Reading Disability (RD) has traditionally been characterized as difficulty in learning to read despite intact sensory functioning, average intelligence, and an adequate educational background (Kibby et al., 2004). Diagnosis has typically been based on the standard score discrepancy model, although, as previously discussed, this method of identification has come under increasing scrutiny as it has in all forms of LD. Nevertheless, significant progress in this area of research has been made. In particular, a substantial amount of evidence has pointed to phonological processing deficiencies as the central contributing factor of RD (Kibby et al., 2004). Other processes thought to be involved in RD include working memory, visual spatial processing deficits, executive functioning deficiencies, and impaired memory function.

Research in reading has shown that phonological processing deficits distinguishes word-level reading disabilities from other forms of LD and from typically achieving readers (Share & Stanovich, 1995). The greater the severity of phonological processing deficits, the more severe the reading disability (Fletcher, Morris, & Lyon, 2006). Wolf and Bowers (1999) argued that while phonological processing is a significant contributor to word recognition, reading also involves accuracy and fluency. The authors contend that phonological deficits are also apparent in poor spellers. There is, however, a subgroup of students with RD that read and spell adequately but exhibit fluency deficits that are independent of phonological processing. These fluency deficits are correlated with rapid naming tasks. Studies have found that pause time is highly correlated with both reading fluency measures and reading accuracy (Georgiou, Parrila, & Kirby, 2006).

Wolf and Bowers (1999) proposed a double-deficit model of reading deficits that include three subtypes of reading deficits. The first subtype is characterized by deficits in both phonological processing and rapid naming. The second subtype is characterized by deficits in phonological processing alone, and the third, deficits in rapid naming tasks. Children with double-deficits, or phonological processing and rapid naming deficits, tend to have more severe reading difficulties.

Phonological awareness is most strongly related to reading during the first two years of school and the relationship between naming speed and reading increased with grade level. One study found that children with deficiencies in both phonological awareness and naming speed were most likely to develop reading difficulties by the fifth grade (Kirby, Parilla, & Pfeiffer, 2003). Another study examined how measures of articulation rate, verbal short-term memory, naming speed, and phonological awareness tasks administered in Kindergarten and repeated in the first grade predict word reading and passage comprehension in the first, second, and third grades. The authors found that phonological awareness was the strongest predictor of reading when measured in grade one (Parrila, Kirbly, & McQuarrie, 2004). Swanson (2004) further argued that children with RD have WM deficits related to the phonological loop, which is a component of WM that is involved in the retention of speech based information. Holsgrove and Garton (2006) found that phonological processing (along with syntactic processing) was a predictor of reading comprehension and that the phonological loop from Baddeley's (1986) model played a small, but significant role in processes related to reading comprehension.

The relationship between intelligence and RD has been somewhat controversial in the literature, mostly because its role is not fully understood. It has been argued that the role of IQ is not as important in reading as processes such as memory, decoding, listening comprehension, and processing speed as they are thought to have a more direct effect on reading comprehension (Meyer, 2000). However, Tiu et al. (2003) argued that it is highly probable that a relationship between intelligence and RD does exist because processes that have been linked to reading achievement (processes such as working memory and processing speed) are also related to intelligence. Although a correlation between intelligence and reading has been reported in the literature (Tiu et al., 2003), the evidence has not been conclusive (Meyer, 2000). For example, children with poor reading skills have a range of intellectual ability, from low to average to above average. Wadsworth et al. (2000) suggested that there may be different underlying causes of reading deficits in children with higher IQs than those with lower IQs (age discrepant).

Cognitive Processes Related to Mathematical Disabilities

Mathematical Disability (MD), also called Mathematics Disorder in the literature, is defined by the DSM-IV-TR as "mathematical ability…measured by individually administered standardized tests (that) is substantially below" one's chronological age, age-appropriate education, and measured intelligence (APA, 2000). While it appears WM deficits in students with RD may be related to phonological deficits (e.g. Swanson 1999b), poor memory performance in students with MD appears to be related to choice of strategy (e.g. Geary & Brown, 1991) and higher order thinking skills such as executive processing (Bull, Johnson, & Roy, 1999; Keeler & Swanson, 2001).

Much of the research investigating the influence of cognitive processes on mathematics ability has included a very narrow set of domain-specific conceptual and procedural processes such as phonological or working memory, storage and retrieval from long-term memory, and visual processing abilities (Floyd, Evans, & McGrew, 2003). A study by Davis, Parr, and Lan (1997) examined the characteristics of LD in reading, spelling, and arithmetic via the Revised Woodcock-Johnson Psychoeducational Battery. The authors found that students with MD had weaker non-verbal skills than students with reading and spelling deficits. The students with both reading and spelling deficits had stronger nonverbal skills. In a sample of first to fourth graders, Vukovic and Siegel (2010) found that MD could be characterized by deficits in math concepts and phonological decoding. There was, however, some evidence for the involvement of WM, processing speed, and numerical reasoning. On the other hand, Landerl et al. (2004) found no causal evidence that WM is a feature of MD.

Part Three: Working Memory

The third section of the literature review is dedicated to the discussion of WM as a subset of the broader memory field and its reported association with LD. In particular, the work of Baddeley (1986) is discussed and the LD literature pertaining to his model is reviewed. The rest of the section focuses on other recent findings pertaining to WM, LD, and LD subtypes.

The Origins of Working Memory

Cognitive psychologists have long differentiated long-term memory (LTM) (information that is stored permanently) from short-term memory (STM) (information that is stored temporarily) (Atkinson & Shiffrin, 1971). As such, researchers in the LD field began studying memory and how it may or may not be related to LD. According to Kibby et al. (2004), several researchers have concluded that there is a link between LD (i.e. reading disability) and STM. Swanson (2005), however, argued that although there is a correlation, the correlation is very weak. This issue has never been entirely resolved as researchers began focusing more on a process closely related to STM, called working memory (WM).

STM refers to the storage of information over short periods of time without any competing cognitive demands. Theoretical accounts for STM and WM typically distinguish the two systems by the STM storage-only capacities and the more flexible, broader nature of WM (Gathercole et al., 2006). Although both WM and STM contribute to learning, their contribution is quite distinct. WM is involved in the development of complex skills and knowledge in mathematics and literacy. STM is important for learning the sound structure of new words (Gathercole & Alloway, 2006). WM deficits are also very rare in samples of children without LD (Pickering & Gathercole, 2004) and do not appear to be mediated by either IQ or verbal abilities (Gathercole et al., 2004).

Pickering and Gathercole (2004) reported that WM impairments are more typical in children who have difficulties in both literacy and mathematics than to those whose difficulties are restricted to literacy alone (Gathercole & Alloway, 2006). Furthermore, STM skills do not have as strong an association to general cognitive performance and academic skills (Daneman & Merikle, 1996).

Although similar to STM, WM involves additional processes. STM typically involves the passive storage of small units of information, whereas WM involves preserving information while simultaneously processing other information (Swanson & Siegel, 2001).

A simple set of illustrations can be used to differentiate between the two systems: Suppose an individual asks someone for the address of a local restaurant. He listens to the address, gets a piece of paper and writes it down. The act of hearing something and recalling it (writing it down) a short time later is an example of STM. A second individual asks a passerby for the address of a local restaurant. Upon hearing the address, it becomes apparent that she does not know where the address is located and asks for further directions. While listening to the directions, she recites the address to herself so she does not forget it. This is an example of WM: preserving information (the address) while simultaneously processing information (the directions) (Swanson & Siegel, 2001).

Baddeley's Conceptualization of Working Memory

The idea of a WM system was first introduced by Baddeley (1986) and his colleagues and eventually grew into a groundbreaking theory in the memory field. Baddeley's ideas and subsequent model have become the most prominent and widely accepted model of WM to date. Broadly speaking, Baddeley (1986) characterizes WM as a system of limited capacity involved in preserving information while simultaneously processing other information. According to Baddeley, WM is comprised of three systems: the phonological loop, the visual spatial sketchpad, and a control system, called the central executive. A fourth component was later added to the model called the episodic buffer although little research has been conducted on this component of the model to date.

The phonological loop is associated with speech and auditory-based information and is involved in the temporary storage of verbal information that is maintained through a process called subvocal articulation (Swanson & Siegel, 2001). Subvocal articulation can be thought of as the subvocal repetition of information to oneself. The visual spatial sketchpad is associated with the storage, maintenance, and manipulation of visual and spatial information (Baddeley, 1998). It plays a central role in the generation and manipulation of mental images (Swanson & Siegel, 2001). The role of the third component of the model, the central executive, is to control and regulate WM. The central executive coordinates the phonological loop and visual spatial sketchpad by focusing and switching attention between the two subsystems. It also activates representations within LTM (Baddeley, 1986; Swanson & Siegel, 2001). The episodic buffer acts as an intermediary between LTM and the other working memory components. Information found in long-term memory is brought to conscious awareness through the episodic buffer and provides stored information to the other WM systems. It was previously believed that the episodic buffer was a part of the Central Executive, however subsequent research has indicted that it is a stand-alone subsystem (Baddeley 2000; Leffard et al., 2006).

Swanson and Siegel (2001) provided evidence of executive processing deficits in children with LD on tasks requiring complex divided attention and monitoring abilities (the suppression of irrelevant information). The authors found reduced performance on both visual-spatial and verbal tasks that involve simultaneous processing and storage of information. Swanson and Siegel believe that persons with LD often have normal intelligence "because the information they experience in their environment does not always place high demands on their WM." For example, it is possible for children with LD to perform some tasks independently but when required to perform these same tasks simultaneously, they have difficulty doing so. This hypothesis, however, requires further investigation.

Although most of the existing research on WM focuses on one specific component of Baddeley's model, Kibby et al. (2004) tested the entire model within the context of a single study. Kibby et al. reported that children with RD (age 9-13) had an impaired phonological loop, which appears to be specific to the phonological store. It was also reported that the visual-spatial sketchpads of children with RD were as intact as the control group suggesting that those students "should be able to store visual material as well as good readers and…should be able to perform two tasks simultaneously as well as controls, provided that neither task involves verbal material." Although deficits related to the phonological loop have been linked to LD, not all researchers agree on what role, if any, the visual spatial sketchpad plays.

General Characteristics of Working Memory Deficits in Learning Disabilities

There are some general WM-related manifestations that are typically noted in individuals with LD. These manifestations include difficulty remembering familiar items such as numbers, letters, and words, as well as unfamiliar items that can be easily named and stored phonetically in memory (Swanson, 2005). Currently, it is thought that children with LD use fewer rehearsal mechanisms and perform poorer on tasks that require short-term retention of ordered information than their non-LD counterparts (Swanson & Siegel, 2001).

Studies also have shown that WM may be strongly related to academic performance (Swanson & Siegel, 2001). Evidence linking mathematics, writing, and reading to WM has been demonstrated in several studies. For example, Keeler and Swanson (2001) found that math achievement, WM, and strategy knowledge are related. Significant predictors of achievement in mathematics include strategy knowledge along with verbal and visual-spatial WM. Regarding the writing process, studies have shown that sentence complexity and writing coherence is related to larger WM spans (McCutchen, 2000). It has been proposed by some researchers that children with LD have metacognitive strategy limitations. Swanson (2004), however, has argued that children with RD and MD do not have metacognitive strategy deficits, but may exhibit processing difficulties related to the executive system instead.

Gathercole et al. (2006) found that WM skills were significantly related to the severity of LD in both reading and mathematics in a sample of children with RD. Similarly, Henry (2001) found that when compared to children with average abilities, those with more severe LDs had greater WM impairments. Henry also reported that children with moderate LD did not differ significantly from those with mild LD on simple span tasks, but performed significantly poorer than those with mild LD on more complex span tasks.

Working Memory and Reading Disabilities

Verbal WM deficits have been strongly linked to poor reading performance (Swanson & Siegel, 2001; Howe et al., 1999). Verbal WM is associated with Baddeley's (1986) phonological loop, which involves the temporary storage of verbal information that is maintained through sub-vocal articulation. Howe et al. (1999) found that individuals with RD have poorer memory function than normal readers. It has been widely reported that recalling verbal information (associated with reading tasks) is more difficult for students with LD than for those without LD (McNamara & Wong, 2003). Kramer et al. (2000) found that compared to controls, individuals with RD learned items more slowly, recalled fewer words, and performed less well on a recognition condition. The authors suggested that individuals with RD have normal retention and retrieval systems but are deficient in their ability to learn new verbal material (Kramer et al., 2000). Research has shown that WM may account for significant variance in LD readers' performance on comprehension tasks (Swanson, 1999a; Swanson, 1999b). Readers with more WM capacity may have greater resources available for storage while comprehending text, while readers with a smaller WM capacity may not have as many resources available for information maintenance for comprehension (Swanson & Siegel, 2001).

Despite these and other findings, researchers have not yet identified a clearly predictable pattern of reading task difficulties and memory deficits (Howe et al., 1999). The most consistent finding in the literature is that letters and numbers presented verbally are more difficult for individuals with RD to recall (Howe et al., 1999). Further complicating matters, much of the existing research has not controlled for possible co-morbid disorders such as ADHD (Howe et al., 1999). McNamara and Wong (2003) have suggested that the processing problems associated with WM difficulties may extend beyond reading and academic tasks and into everyday life although few studies aside from their own have investigated this idea.

Working Memory and Mathematics Disability

Some researchers have suggested that WM deficits are a factor in mathematical disability (MD) (Bull & Johnston, 1997; Siegel & Ryan, 1989; Swanson, 1993). WM is thought to be involved in memorization tasks, the spatial representation of mathematical problems, as well as the initiation, directing, and monitoring of procedures in the mathematical process (Cornoldi et al. 2001**;** McLean & Hitch, 1999). According to Swanson (2004), WM as it relates to mathematics likely involves a workspace where partial and complete units of information can be temporarily stored and used for solving problems. When compared to children without MD, researchers have demonstrated that the retrieval of answers directly from memory is less likely to occur in children with MD. Instead, these children tend to depend more on counting out loud or using their fingers (Swanson & Rhine, 1985).

Much of the current research pertaining to WM and MD has focused on mathematical word problems. Students with LD often have considerable difficulty on tasks that involve both WM and solving mathematical word-problems (e.g. Swanson, 1993). Because mathematical word-problems are a form of text that involves decoding and comprehension, it is thought that the phonological system is involved in this process (Swanson & Sachse-Lee, 2001). As understanding word problems involves a complex interaction of both text comprehension and mathematical processes, solution accuracy may be related to the proficiency of the WM system (Swanson & Sachse-Lee, 2001). The proficiency of this system is necessary to construct a coherent and meaningful interpretation of the word problems (Swanson, 2006). As such, there is growing evidence that students who experience difficulty in math word problems have particular difficulty with tasks that involve mentally constructing an adequate representation of the problem (Swanson & Sachse-Lee, 2001).

In summary, as far as the existing research is concerned, WM is not a "unitary well-defined cognitive component" which makes the interpretation of data more complex. Also, the use of different assessment techniques as well as varied criteria for MD across studies has made comparing results difficult (Cornoldi et al., 2001).

Part Four: Wechsler's Tests, Working Memory, and Learning Disabilities

The next section of the literature review will examine research that has utilized Wechsler's tests (e.g.WISC-R; WISC-III; and WISC-IV) in relation to LD, WM, and other cognitive processes related to LD. In terms of studies that have looked specifically at WM in relation to the Wechsler tests (WISC-III, WISC-IV), there were surprisingly few available for review. Most studies that touched upon Wechsler WM measures did so in a broader sense, usually in terms of analyzing overall subtest scatter and profile analysis of other disorders.

Leffard et al. (2006) reviewed cognitive tests that included measures of WM, one of which was the WISC-IV Working Memory Index (WMI). Although the WISC-IV identifies three subtests (two core and one supplemental) loading on the WMI, the authors concluded that WMI subtests only measure rehearsal and transformation of phonological information and that the visual spatial sketchpad (from Baddeley's model) is not adequately assessed in the main test battery. The authors suggest that it is unlikely that the Letter-Number-Sequencing subtest taps the visual spatial sketchpad, which focuses on object characteristics such as shape, color, and location (Baddeley, 2003; Leffard et al., 2006). Therefore a more accurate interpretation of the WMI scores is to conceptualize it as a measure of phonological WM. As far as the supplemental WISC-IV Arithmetic subtest is concerned it is the least pure WM task as it involves mathematical skills (Leffard et al., (2006).

The WISC-IV and the Diagnostic Utility of Profile Analysis

The notion that diagnostic information can be obtained from analyzing individual cognitive subtest scores or patterns is an idea that has been addressed in the literature for several years (Hale et al, 2007). For this reason, special group test scores are provided in the WISC-IV manual to assist in diagnostic assessment. However, precaution must be taken in the interpretation of this information when one considers the small sample sizes and lack of random selection amongst certain populations (such as LD) used in the WISC-IV norm studies. Because participants were selected from multiple private clinical settings, there is no guarantee that identical criteria for the diagnoses of disorders such as LD were used. Based on the data, the diagnostic utility for LD of the WISC-IV alone is unknown (Kaufman, Flanagan, & Alfosno (2006).

Authors such as Sattler (2008) provide both statistical and clinical evidence of subtest attributes to interpret patterns of performance. Typical analyses consists of a global interpretation of test scores, followed by interpretation of composite or index scores, then subtest clusters that may share common characteristics (Hale et al., 2007). There are, however, concerns about the reliability and validity of subtest analysis used in isolation although several authors support this practice for determining hypotheses about strengths and weaknesses and for developing interventions for specific needs (Hale et al., 2001). Nevertheless, Mayes and Calhoun's (2004) research supports the reliability and validity of profile analysis in children with autism, ADHD, and LD. The authors found that most children with LD had low Coding (subtest) or FDI (Freedom From Distractibility Index, now called the Working Memory Index on the WISC-IV) scores without low Comprehension (subtest) scores. Similarly, Mayes et al. (1998) found that 8-16 years olds with LD scored lower on the FDI index relative to Full Scale IQ (FSIQ) than children without LD. Other studies have reported that children with LD scored lower on the WISC-R FDI index (Arithmetic, Coding, Digit Span subtests) relative to other factors (Kaufman, 1994; Wielkiewicz, 1990).

Other studies have used profile analyses of Wechsler tests as well. Calhoun and Mayes (2005) reported that in a referred sample, students with neurological disorders (including LD) had lower PSI (Processing Speed Index) and FDI Index scores than VCI (Verbal Comprehension Index) and POI (Perceptual Organization Index) scores. Mayes and Calhoun (2007) found that on the WISC-IV, verbal intelligence is more strongly related to academic achievement whereas WMI and PSI were more important in determining LD in children with ADHD. D'Angiulli and Siegel (2003) reported that children with RD and AD had lower scores than the typical achievers on all vocabulary subtests. They also reported that although children with reading disabilities and arithmetic disabilities had significant differences between WISC-R Verbal (VIQ) and Performance IQ (PIQ) scores, many typically achieving children showed significant differences as well. The authors thus concluded that LD performance patterns on the WISC-R test were not reliable enough to be used for LD diagnosis alone.

Summary

This review has demonstrated that despite its inclusion in most recognized LD definitions, the usefulness and appropriateness of the discrepancy method has been called into question by a growing number of researchers (e.g. Siegel, 1989; Stanovich, 2005). At this time, research pertaining to differences between discrepant and non-discrepant LD students is inconclusive (Meyer, 2000). This literature review has also shown that the LD field is in a state of flux. In the long term, this may serve the field well as researchers are increasingly questioning existing practices and looking for more appropriate ways to define and diagnose LD. In the short term, interpretation and generalization of the LD research is extremely difficult.

The literature review also addressed some of the key research findings regarding the cognitive processes associated with LD. Although numerous findings were reported, studies investigating cognitive profiles of children with LD are difficult to interpret primarily because of methodological inconsistencies. This may be due to researchers' use of incomplete test batteries resulting in compromised factor scores; varying criteria for determining the presence or absence of LD; variations in LD sample size; and the use of different factor analytic methods (Filippatou, Dimitropoulou, & Sideridis, 2009). Thus the primary cognitive mechanisms that separate MDs from RDs remain unclear and require further investigation (Swanson & Jerman, 2006).

Rationale and Research Questions

Children identified as having LD via the discrepancy method have IQ scores that fall within the average range with a significant discrepancy in their achievement scores. Generally speaking, this group also tends to have higher IQ scores than those children identified by means of low achievement alone (Proctor & Prevatt, 2003). For individuals identified via the low achievement method, diagnosis is based upon scoring below the 25^{th} percentile on standardized measures of achievement alone, although authors such as Swanson and Siegel (2001) require an IQ score of at least 80 to rule out mental retardation. As the literature review has demonstrated, children with LD often present with WM deficits. However, because of methodological uncertainties in sampling procedures compounded by definitional inconsistencies, it is difficult to know if students with LD diagnosed under different criteria on known cognitive processes differ significantly.

The first objective of this investigation is to determine whether students with DLD and NDLD can be differentiated on the basis of the WISC-IV measures. The WISC-IV measures compared in the study are Verbal Comprehension Index (VCI), the Perceptual Reasoning Index (PRI), the Processing Speed Index (PSI) and the Full Scale IQ (FSIQ). Much of the recent research suggests very few differences exist between students with DLD and NDLD. However, to the best of this researcher's knowledge, WM has not been compared in these two groups of students. Four questions in the current study address this issue. The second objective of this investigation is to compare the cognitive profiles of students with RD, MD, and GLD (generalized learning disabilities with deficits in both reading and mathematics). As stated in the literature review, the cognitive processes of different forms of LD are not fully understood. Moreover, there is a considerable lack of literature related to WISC-IV measures and LD. Two questions in the study will specifically address this issue.

Based on the context of this literature review, the following questions are posed:

1. Do WISC-IV WM scores (Digit Span, Letter Number Sequencing,

WMI) differ significantly in students who meet the criteria for discrepancy-based LD (2 SD as per DSM-IV-TR guidelines) from students with non-discrepant LD (an IQ of 80 or above, scoring below the 25^{th} percentile on WIAT-II achievement measures)?

2. Are there differences in the WISC-IV VCI, PRI, and PSI of children with Below Average WM Index Scores when compared to children whose WM Index scores fall in the Average or Above Average range?

3. Are there differences in the WIAT-II achievement profiles of children with Below Average WM Index Scores when compared to children whose WM Index scores fall in the Average or Above Average range? Do differences still exist if WISC-IV Index Scores (VCI, PRI, PSI) and Full Scale IQ are controlled?

4. Are there differences in WM in students with Reading Disability (RD), Math Disability (MD), and Generalized Learning Disability (GLD)?

5. Are there significant differences in WISC-IV psychometric profiles of students who have a Reading Disability (RD), Math Disability (MD), and Generalized Learning Disability (GLD)?

6. Can Reading Disability (RD) and Mathematics Disability (MD) be predicted by WISC-IV Index Scores?

CHAPTER III

Method

This study is considered retrospective in nature as existing, secondary data was examined in an effort to discover relevant associated factors. The data were made available to the researcher through a private school psychology firm located in central Alberta. This firm holds psychological assessment contracts with several school boards throughout central and northern Alberta. The data was initially obtained for educational assessment purposes. The ethics committee overseeing the Department of Educational Psychology at the University of Alberta granted permission for the analyses of this data and approval to commence with the current study.

Procedure

Initial Assessment/ Test Administration

The following procedures were used to obtain the original data: Data obtained for this study was part of an existing database of student test scores initially collected by a private school psychology firm for school assessment and programming purposes. Most students were initially identified for assessment because the classroom teacher had concerns about the students' achievement in either reading or mathematics. In most cases, students were referred to the school special education resource teacher who then made a formal referral for assessment. Other reasons for referral included individualized program planning, evaluation of learning and behavior, and to determine individual strengths and weaknesses of students. Prior to the assessment, parents and/or legal guardians of minors signed written consent providing permission for the data (test scores) to be used for research purposes at a later date. Student assent was also obtained prior to the assessment. Students were individually assessed at their home school between 2005 and 2009 by a total of six registered psychologists contracted to the psychology firm. Two of the psychologists have doctoral level training and four of the psychologists have masters level training.

All student entries in the database were administered the WISC-IV and an achievement test called the WIAT-II. Standardized testing procedures were followed as outlined in the respective test manuals. After the assessment, the two senior (doctoral level) psychologists examined test protocols and interpretive reports to ensure the accuracy of test administration, scoring, and interpretation. Test results were shared with parents and school staff following the assessment. A written psychological report outlining results, interpretations, and recommendations was provided to the school and to the parents approximately one month following the assessment.

Data Review and Clinical Decision Making Process

Data provided by the psychology firm were reviewed in backward order from 2005 through 2009 until a sample of 350 students who met inclusion criteria was formed. No identifiable data was collected other than the students' first and last initials, school, and, date tested. The initials were then paired and replaced with a numeric code. The list of student initials and school was destroyed upon completion of the data review. Only subjects with valid and complete data sets for all the variables were included in the study. This reduced the original sample size from 350 to 338.

The clinical decision-making process involved determining whether students were administered all ten core subtests of the WISC-IV and six selected WIAT-II subtests (Word Reading, Reading Comprehension, Pseudoword Decoding, Spelling, Numerical Operations, and Math Reasoning). This was essential because all ten subtests are required to obtain a Full Scale score on the WISC-IV and the five of the six selected subtests (excluding Spelling) on the WIAT-II were required for Reading and Mathematics Composite scores. Other criteria required for inclusion in the sample was that the subject was experiencing difficulty in either reading and/or mathematics, as indicated on the client intake form. Students with WISC-IV Full-Scale Index scores less than 80 were not included in the overall sample to rule out mental retardation. Once these criteria were met, the remaining students in the database was further examined and subjects were selected that met the criteria listed in Table 1 and Table 2. Selected subjects (*n* =338) were further categorized and coded into two WM groups and three LD groups. Table 1 and Table 2 present specific inclusion criteria for all LD and WM groups in the study.

Table 1

Criteria for Inclusion in LD Groups

1) Discrepant Learning Disability Group (Research Question 1):

A Full-Scale WISC-IV Full Scale Index score of 80 or above and achievement scores in reading and/or mathematics are at least two standard deviation (SS=30 points below the WISC-IV Full Scale Index core) on one or more of the following WIAT-II reading and/or mathematics subtests or composite scores: Word Reading; Reading Comprehension; Pseudoword Decoding; Numerical Operations; Math Reasoning; Reading Composite; Mathematics Composite.

2) Non-Discrepant Learning Disability Group (Research Question 1):

Full-Scale WISC-IV Full Scale Index score of 80 or above with WIAT-II reading and/or mathematics subtest and/or composite scores below the 25^{th} percentile.

Table 2

Criteria for Working Memory and Learning Disability Subcategories

1) Low Working Memory Group (Research Question 2):

WISC-IV Working Memory Index score of 89 or below.

2) Average/Above Average Working Memory Group (Research Question 2):

WISC-IV Working Memory Index score of 90 and above.

3) Reading Disability Group (Research Question 3):

WISC-IV Full Scale Score of 80 or above and one or more of the following WIAT-II subtest and/or composite scores below the 25th percentile: Word Reading; Reading Comprehension; Pseudoword Decoding; Reading Composite score. All WIAT-II mathematics subtest and composite scores were above the 25th percentile.

4) Mathematics Disability Group (Research Question 3):

WISC-IV Full Scale Score of 80 or above and one or more of the following WIAT-II subtest and/or composite scores below the 25th percentile: Numerical Operations; Math Reasoning; Mathematics Composite score. All WIAT-II reading subtest and composite scores were above the 25th percentile.

5) Generalized Learning Disability Group (Research Question 3):

WISC-IV Full Scale Score of 80 or above and one or more of the following WIAT-II reading subtest and/or composite scores below the 25th percentile: Word Reading; Reading Comprehension; Pseudoword Decoding; Reading Composite score. Additionally, the participant must also display one or more of the following mathematics subtest and/or composite scores below the 25th percentile: Numerical Operations; Math Reasoning; Mathematics Composite Score.

Participants

Subjects included in this study consisted of a non-random, clinical sample of 338 students aged 6 to 16 years who were referred to the psychology firm by school staff for individual psycho-educational assessments between 2005 and 2009. Subject referrals came from a total of 25 schools representing 3 central and northern Alberta school districts. Two of the school districts were urban and one of the districts was rural. The mean age for the sample was 130.26 months. Subjects consisted of 236 males (69.8%) and 102 females (30.2%). The mean age for the sample group at the time of assessment was 130.26 months (SD = 34.31) with a mode of 95.00 months. The range of age for participants was 72 to 199 months. Grade range was Kindergarten to grade 11.

Instrumentation

The Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV)

The Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV) is an individually administered test of cognitive ability that assesses the intelligence of children between the ages 6 years 0 months to 16 years 11 months. Composite scores on four domain areas (Verbal Comprehension Index, Perceptual Reasoning Index, Working Memory Index, and Processing Speed Index) are provided as well as a Full Scale Score that represents a child's general intellectual ability (Wechsler, 2003). Normative data was stratified on key Canadian demographic variables (i.e. geographic region, age, sex, race/ethnicity, parental education level) from the 2001 Census data (Statistics Canada, 2002).

Numerous revisions have been made to the WISC-IV that differentiates it from its predecessors. A notable change is the omission of the Verbal and Performance index scores. In its place, four composite scores were introduced to better represent the domains of cognitive functioning (Burns & O'Leary, 2004). As stated in the technical manual, the primary goals of the revisions were to update the theoretical foundations, enhance clinical utility, increase developmental appropriateness as well as user-friendliness, and to improve its psychometric properties (Burns & O'Leary, 2004; Wechsler, 2003).

One of the foremost improvements to the Wechsler test, as claimed in the technical manual, is the revisions to the WM measures (Wechsler, 2003). According to the manual, WM is the "ability to actively maintain information in conscious awareness, perform some operation or manipulation with it, and produce a result" (Wechsler, 2003, p. 8). The Working Memory Index (WMI) is made up of three subtests, two core subtests and one supplemental subtest. Digit Span (DS) and Letter-Number –Sequencing (LNS) make up the two core subtests. DS is composed of Digit Span Forward (DSF) and Digit Span Backward (DSB).

DSF involves the examiner reading aloud a series of numbers that is repeated by the examinee. This subtest measures auditory short-term memory, attention, concentration, and sequencing skills (Sattler & Dumont, 2004). The second part of the subtest, DSB, involves the examiner reading a series of numbers and the examinee repeating the numbers is reverse order. DSB involves WM, transformation of information, visual spatial imaging, and mental manipulation (Reynolds, 1997; Sattler & Dumont, 2004). Separate processing scores are included for DSF and DSB as recent research suggests that DSB places greater emphasis on WM processes (de Jonge & de Jonge, 1996).

Letter-Number Sequencing is also a core WM subtest. The subtest involves the examiner reading a sequence of letters and numbers in a mixed order. The examinee is required to recall the numbers in ascending order and the letters in alphabetical order. This test was partly based upon the work of Gold et al., (1997) and involves mental manipulation, sequencing, short-term auditory memory, visual spatial imaging, attention, and processing (Crowe, 2000; Sattler & Dumont, 2004).

The supplemental WMI subtest is Arithmetic, which requires the examinee to mentally calculate and solve a series of arithmetic word problems within a specific period of time. The test involves mental manipulation, attention, concentration, short-and long-term memory, mental alertness, and numerical reasoning ability (Sattler & Dumont, 2004). It is the "least pure' WM subtest because processes outside the definition of WM are also involved (e.g. mathematical skills) (Leffard et al., 2006). Thus, the Arithmetic subtest scores were not used in the calculation of the WMI and were not used in this study. Although the WISC-IV WM subtests are not suited for isolating specific WM subcomponents (i.e. phonological loop, visual-spatial control pad, central executive), from a clinical perspective these subtests help determine if a more detailed WM assessment is warranted.

Reliability. Evidence for internal consistency was obtained through the normative sample and the split-half reliability method (Wechsler, 2003). Average reliability coefficients (overall average from 6 years to 16 years) for WISC-IV composite scales were as follows: Verbal Comprehension Index (VCI): .93; Perceptual Reasoning Index (PRI): .90; Working Memory Index (WMI): .91; Processing Speed Index: (.90); and Full Scale (FS-IQ): .96. These are considered generally high (>.90+) (Kaufman, et al., 2006). Individual subtest reliability coefficients (overall average from 6 years to 16 years) ranged from .79 (Comprehension) to .88 (Matrix Reasoning and Letter-Number-Sequencing).

Validity. The validity of a test is traditionally measured through content validity, criterion-related validity, and construct validity (Wechsler, 2003). Content validity refers to the degree to which the test items represent the trait being measured. Based on response processes, the majority of WISC-IV subtests have strong theoretical and empirical evidence of validity (Wechsler, 2003). Subtests retained from previous versions of the WISC have an extensive body of research on response processes during subtest performance (e.g. Kaufman, 1994; Sattler & Dumont, 2004). To establish additional evidence of response process validity for the new subtests, the test manual states that extensive literature reviews were conducted, along with empirical examination and expert consultation (Wechsler, 2003). The validity of the WISC-IV is also supported by evidence of correlations with other measures of global ability. For example, the WISC-IV FS-IQ is substantially correlated with WAIS-IV, WPPSI-II, and WISC-III FS-IQ (.89, U.S. norms) (Kaufman, 2003).

Wechsler Individual Achievement Tests, Second Edition (WIAT-II)

The Wechsler Individual Achievement Tests, Second Edition (WIAT-II) is an individually administered test of academic achievement that is used to assess achievement skill level, special education placement, and clinical appraisal. It can also be used to assist a practitioner in the diagnosis of learning disabilities. The WIAT-II consists of nine subtests (Word Reading, Numerical Comprehension, Spelling, Pseudoword Decoding, Math Reasoning, Written Expression Listening Comprehension, Oral Expression) and five composites (Reading, Mathematics, Written Language, Oral Language, and Total Composite). The WIAT-II was chosen as an assessment tool by the psychology firm because it is empirically linked with the WISC-IV, thus providing valid discrepancy scores to help make comparisons between ability and achievement more meaningful. Scores from the WIAT-II are an integral component of the data set related to the present study as the test was chosen to represent academic achievement for the sample groups.

The WIAT-II is an assessment tool that can be used for students from K-12. Supplemental normative data is also available for college students and adults. Canadian norms (Canadian supplement) from the WIAT-II Canadian Scoring and Normative Supplement for Grades K-16 were used for interpreting raw test scores. Normative data specific to examinees in Grades K-16 (or ages 5-19) are included in the Canadian supplement. Normative data include age and grade-based standard scores, percentile ranks, normal curve equivalents, stanine scores, as well as subtest and composite confidence intervals. Information about the differences required for base rates and statistical significance are also included in the Canadian supplement.

The mean standard score of the WIAT-II is 100 with a standard deviation of 15. Age-based reliability coefficients for the total composite score ranged from .96 to .98. Individual subtest reliability varied somewhat ranging from .72 (Listening Comprehension, 15-year-old) to .99 (Word Reading, ages 5-7). Content, construct, and criterion validity are also reportedly high indicating that the WIAT-II measures what it is supposed to measure.

In terms of the relationship between the WISC-IV and the WIAT-II, correlations between FS-IQ and WIAT-II composites ranged from .75 (Oral Language) to .78 (Reading and Math), meaning that 56% to 60% of the variance in these achievement domains can be explained by the WISC-IV Full Scale Index score (Kaufman, 2006). Correlation between WIAT-II Total Achievement Score and WISC-IV FS-IQ is .87 (76% of explained variance) and are one of the highest correlations reported between achievement and IQ (Kaufman, Flanagen, & Alfonso, 2006).

CHAPTER IV

Results

Descriptive analysis of subject WISC-IV and WIAT-II test scores are first presented in this section followed by analyses of the LD outcomes. The data were examined for violations of normality and the presence of outliers. Analyses were run with the original data and then repeated with the adjusted scores to control for the possible effect of outliers and extreme scores.

The data that was made available to the researcher had one intellectual measure (WISC-IV) that consisted of four index scores (Verbal Comprehension Index, VCI; Perceptual Reasoning Index, PRI; Working Memory Index, WMI; and Processing Speed Index, PSI), one Full Scale IQ score (FS), and ten core subtests. The data also had one standardized achievement measure (WIAT-II) that consisted of two composite scores (Reading Composite and Mathematics Composite) and 6 subtest scores. Six questions were investigated in total. Resulting analyses consisted of multivariate analysis of variance (MANOVAs) when questions presented with two or more dependent variables; analysis of variance (ANOVAs) when questions presented with two or more independent groups; analysis of covariance (ANCOVA) to test whether certain factors may have an effect on the outcome variable after removing the variance for which quantitative predictors account; and Logistic Regression to determine group membership. The Bonferroni correction was used to address the problem of multiple comparisons. Table 3 and Table 4 present the descriptive statistics for the WISC-IV and the WIAT-II data.

Table 3

Sample Group Statistics for WISC-IV Index Scores

(N=338)	VCI	PRI	WMI	PSI	FS	Age
Mean	90.70	96.00	88.54	94.65	89.37	10.40
Median	91.00	95.00	88.00	91.00	88.00	10.00
Mode	93.00	93.00	86.00	91.00	84.00	7.00
SD	9.48	11.10	9.70	50.74	7.06	2.87
Range	65.00	60.00	58.00	38.00	44.00	10.00
Min	65.00	72.00	56.00	59.00	80.00	6.00
Max	130.00	132.00	114.00	97.00	124.00	16.00

Note. WISC-IV = Wechsler Intelligence Scale for Children, 4th Edition (Wechsler, 2003); VCI = Verbal Comprehension Index; PRI = Perceptual Reasoning Index; WMI = Working Memory Index; PSI = Processing Speed Index; FS = Full Scale score.

Table 4

Sample Group Statistics for WIAT-II Subtest and Composite Scores

(N=338)	MCom	RCom	SP	MR	NO	PD	RC	WR
Mean	79.86	83.40	83.48	83.64	81.68	89.36	85.72	82.87
Median	79.00	83.00	84.00	83.00	81.00	89.00	85.00	83.00
Mode	74.00	81.00	84.00	78.00	78.00	88.00	82.00	86.00
SD	12.07	12.52	14.67	13.01	12.84	12.85	12.87	13.66
Range	76.00	87.00	80.00	87.00	73.00	66.00	82.00	87.00
Min	49.00	42.00	41.00	41.00	49.00	57.00	50.00	40.00
Max	125.00	129.00	121.00	128.00	122.00	123.00	132.00	127.00

Note. WIAT-II = Wechsler Individual Achievement Test, Second Edition (Wechsler, 2002); MCom = Mathematics Composite; RCom = Reading Composite; SP = Spelling; MR = Math Reasoning; NO = Numerical Operations; PD = Pseudoword Decoding; RC = Reading Comprehension; WR = Word Reading.

Data Analyses

The first question sought to determine whether WISC-IV WM scores differ significantly in students who meet criteria for discrepancy based LD (DLD) from students with non-discrepant LD (NDLD). From the dataset, two groups were formed (DLD, n =35; NDLD, n = 35). MANOVA was used to compare the DLD group with the NDLD group on the WISC-IV WMI score, the Letter-Number-Sequencing subtest, and the Digit Span subtest. Results indicated that there were no significant differences between students with discrepant LD and students with non discrepant LD on the WISC-IV Working Memory Index, Letter Number Sequencing and Digit Span subtests, F (3, 67) = .77, $p > .05$.

For the second question, WISC-IV psychometric profiles of children with below average WMI scores (Low WM, $n = 146$) were compared to children whose WM Index scores fell in the Average to Above Average range (High WM, $n = 146$). The dependent variables are not related so a one-way ANOVA compared these groups on three WISC-IV Index Scores: Verbal Comprehension Index (VCI), Perceptual Reasoning Index (PRI), and Processing Speed Index (PSI). Significant differences existed between the High WM group and the Low WM group on the PRI, F (1, 292) = 3.70, $p = .05$. Table 5 presents the findings.

Table 5

ANOVA for High and Low WISC-IV WMI Compared on WISC-IV VCI, PRI, PSI

Source:	*F*	Mean Square	*p*	Mean HWMI	Mean LWMI	SDH	SDL
				Between subjects			
VCI	2.97	292.00	.08	91.44	89.44	10.14	9.66
PRI	3.69	468.16	.05*	96.62	94.10	10. 55	11.91
PSI	1.21	3559.62	.27	91.06	98.03	12.32	75.69

Note. The mean difference is at the .05 level. WISC-IV = Wechsler Intelligence Scale for Children – Fourth Edition (Wechsler, 2003); WMI = Working Memory Index; VCI = Verbal Comprehension Index; PRI = Perceptual Reasoning Index; PSI = Processing Speed Index. Mean HWMI = Mean of High Working Memory Index group; Mean LWMI = Mean of Low Working Memory Index group; SDH = Standard Deviation of the High

Working Memory Index group; SDL = Standard Deviation of the Low Working Memory Index group.

An ANCOVA was then run to factor out the effect of the WISC-IV FS score. Significant differences were found between the High and Low WM groups on the VCI, PRI, and the PSI (see table 6).

Table 6

ACNOVA for High and Low WISC-IV WMI on WISC-IV VCI, PRI, PSI

Source:	*F*	Mean Square	*p*	Mean HWMI	Mean LWMI	SDH	SDL
			Between subjects				
VCI	11.74	546.25	.001*	91.44	89.41	10.17	9.66
PRI	7.90	521.79	.005*	96.46	94.10	10.40	11.91
PSI	4.27	12226.97	.04*	91.10	98.03	12.36	75.69

Note. The mean difference is at the .05 level. WISC-IV = Wechsler Intelligence Scale for Children – Fourth Edition (Wechsler, 2003); WMI = Working Memory Index; VCI = Verbal Comprehension Index; PRI = Perceptual Reasoning Index; PSI = Processing Speed Index. Mean HWMI = Mean of High Working Memory Index group; Mean LWMI = Mean of Low Working Memory Index group; SDH = Standard Deviation of the High Working Memory Index group; SDL = Standard Deviation of the Low Working Memory Index group.

For the third question, the dependent variables were not related so a one-way ANOVA was used to compare the two WM groups on the WIAT-II achievement subtests. The effects of the Low WM group and the High WM group on six WIAT-II subtests (Word Reading, Reading Comprehension, Pseudoword Decoding, Spelling, Numerical Operations, Math Reasoning) was determined and significant differences between the two groups were found on the following WIAT-II subtests: Word Reading, F (1, 290) = 12.04, $p < .01$; Reading Comprehension, F (1, 289) = 8.96, $p < .01$; Pseudoword Decoding, F (1, 290) = 10.84, $p < .01$; Spelling, F (1, 290) = 6.71, $p = .01$; Numerical Operations, F (1, 290) = 12.08, $p < .01$ (see Table 7).

Table 7

ANOVA for High and Low WISC-IV WMI Compared on WIAT-II Subtests

Source:	*F*	Mean Square	*p*
		Between subjects	
Word Reading	12.04	2078.22	.00*
Reading Comprehension	8.96	1362.63	.00*
Pseudoword Decoding	10.84	1731.24	.00*
Spelling	6.71	1346.33	.01
Numerical Operations	12.08	1911.00	.00*
Math Reasoning	5.15	823.06	.02

Note. * Results are Bonferroni corrected. The mean difference is significant at the .008 level. WISC-IV = Wechsler Intelligence Scale for Children – Fourth Edition (Wechsler, 2003); WIAT-II = Wechsler Individual Achievement Test – Second Edition (Wechsler, 2002); WMI = Working Memory Index.

To determine whether differences still exist when VCI, PRI, and PSI are controlled, an ANCOVA was run (see Table 8).

Table 8

ANCOVA for High and Low WISC-IV WMI Compared on WIAT-II Subtests

Source:	*F*	Mean Square	*p*
		Between subjects	
Word Reading	8.64	1397.34	.00*
Reading Comprehension	6.42	866.52	.01*
Pseudoword Decoding	8.74	1385.51	.00*
Spelling	4.98	987.13	.03
Numerical Operations	8.84	1315.88	.00*
Math Reasoning	2.25	301.18	.13

Note. * The mean difference is significant at the .01 level; WISC-IV = Wechsler Intelligence Scale for Children – Fourth Edition (Wechsler, 2003); WMI = Working Memory Index; WIAT-II = Wechsler Individual Achievement Test – Second Edition (Wechsler, 2002).

To determine whether differences still exist when the WISC-IV Full Scale score (FS) is controlled, a second ANCOVA was run. Subsequent analysis found significant differences on only the Pseudoword Decoding subtest. (see Table 9).

Table 9

Full Scale IQ Score as a Covariate for High and Low WISC-IV WMI on WIAT-II Subtests

Source:	*F*	Mean Square	*p*
		Between subjects	
Word Reading	3.34	542.82	.07
Reading Comprehension	.49	61.18	.50
Pseudoword Decoding	6.58	1055.30	.01*
Spelling	3.00	592.81	.09
Numerical Operations	1.35	193.04	.25
Math Reasoning	0.66	83.52	.42

Note. * The mean difference is significant at the .01 level; WISC-IV = Wechsler Intelligence Scale for Children – Fourth Edition (Wechsler, 2003); WMI = Working Memory Index; WIAT-II = Wechsler Individual Achievement Test – Second Edition (Wechsler, 2002).

The fourth question sought to determine if there was differences in WM in students with reading disability (RD), mathematics disability (MD), and generalized learning disability (GLD). MANOVA was used to compare the three LD groups on each of the WISC-IV WM subtests (Digit Span, Letter-Number-Sequencing). Results of the MANOVA indicated that there were not any differences in WM in students with RD, MD, or GLD, F (2, 126) = .48, $p > .05$.

For the fifth question, a one-way ANOVA was conducted to determine if there were any overall differences between RD, MD, and GLD on four WISC-IV Index Scores (VCI, PRI, WMI, PSI). Descriptive statistics are presented in Table 10.

Table 10

Descriptive Statistics for RD, MD, and GLD on WISC-IV VCI, PRI, WMI, and PSI

	LD Subtype	Mean	SD
VCI	1	92.29	9.17
	2	96.84	7.68
	3	87.53	9.61
PRI	1	102.81	11.21
	2	96.72	13.05
	3	93.93	11.31
WMI	1	90.88	9.39
	2	89.53	10.21
	3	86.67	8.98
PSI	1	97.26	13.06
	2	93.21	14.10
	3	90.02	12.02

Note. WISC-IV = Wechsler Intelligence Scale for Children, Fourth Edition (Wechsler, 2003); 1 = RD; 2 = MD; 3 = GLD; RD = Reading Disability; MD = Mathematics Disability; GLD = Generalized Learning Disability: VCI = Verbal Comprehension Index; PRI = Perceptual Reasoning Index; WMI = Working Memory Index; PSI = Processing Speed Index.

The results indicated that there were overall significant differences in students with RD, MD, and GLD, F (8, 244) = 5.861, $p < .01$ (see Table 11). When inflation for Type 1 errors were controlled, significant differences were found on the VCI, F (2, 125) = 11.85, $p < .01$ and on the PRI, F (2, 125) = 6.18, *p*

< .01. PSI was marginally significant, F (2, 125) = 3.26, *p* < .05 (see Table 11).

Table 11

ANOVA for Reading Disabilities, Math Disabilities, and General Learning Disabilities Compared on WISC-IV VCI, PRI, WMI, and PSI

Source:	*F*	Mean Square	*p*
		Between subjects	
VCI	11.85	930.37	.00 *
PRI	6.18	873.98	.00*
WMI	2.16	196.71	.12
PSI	3.26	558.83	.04*

Note. * The mean difference is significant at the .05 level; WISC-IV = Wechsler Intelligence Scale for Children – Fourth Edition (Wechsler, 2003); VCI = Verbal Comprehension Index; PRI = Perceptual Reasoning Index; WMI = Working Memory Index; PSI = Processing Speed Index.

Tukey's HSD post-hoc test identified on which LD group the differences occurred. On the VCI, there were significant differences for RD and GLD (M = 9.30) and for MD and GLD (M = 4.75). Post hoc comparisons also indicated that for the PRI, there were significant differences for RD and GLD (M = 8.88). Finally, post hoc comparisons indicated that for the PSI, significant differences were noted between RD and GLD (M = 7.24).

For the final question, logistic regression was used to predict membership in one of two categories of outcome (RD or MD) on the basis of four WISC-IV Index scores (VCI, PRI, WMI, PSI). Logistic regression helps establish whether or not there is a relationship between group membership and a set of predictors, provides prediction of group membership, and examines which variables predict group membership. The full model, tested against a constant-only model, was statistically reliable, χ^2 (4, N =85) = 17.09, $p < .05$ suggesting that the predictors, as a set, reliably distinguished between the RD and MD groups. Overall, the classification was good. For RD, the correct classification rate was 64.3%. For MD, the correct classification rate was 74.4%. The overall correct classification rate was 69.4%. VCI and PRI were significant predictors of RD and MD, but WMI and PSI were not related to membership in RD or MD. For every one unit increase in VCI the odds of admission increased by a factor of 1.1, while every one unit increase in PRI the odds of admission increased by a factor of .95.

CHAPTER V

Discussion

Findings Related to the WISC-IV Working Memory Index in Learning Disability Groups

DLD vs. NDLD. The current investigation sought to distinguish a sample of students with DLD from a sample of students with NDLD on the basis of WISC-IV WMI scores. The DLD group consisted of students who had at least a two standard deviation discrepancy between their WISC-IV Full Scale Index score and a reading or mathematics subtest/composite score on the WIAT-II. The NDLD consisted of students who scored below the 25^{th} percentile on one or more of the WIAT-II reading or mathematics subtests. The WM measure was the WISC-IV WMI, which is comprised of the Digit Span and Letter-Number-Sequencing subtests. The findings indicate that the two LD groups could not be distinguished by the WMI and are in keeping with the majority of recent published studies that have compared DLD with NDLD.

As indicated in the literature review, an increasing number of experts are questioning the utility and appropriateness of the discrepancy method because differences between DLD and NDLD have been difficult to pinpoint (e.g. Joshi, 2003; Siegel, 1999; Stanovich, 1999, 2005; Sternberg & Grigorenko, 2002). For example, Mazzocco and Meyers (2003) were not able to differentiate between students with MD using the discrepancy method. The authors also reported that discrepant readers did not differ from non-discrepant readers in terms of cognitive functioning or prognosis in the primary school years (Mazzocco & Myers, 2003).

The findings of the current study add to the growing body of evidence that the discrepancy method does not reliably differentiate LD students.

In terms of using WM to differentiate between DLD and NDLD, the results do appear to be in keeping with the findings of Maehler and Schuchardt (2009). Maehler and Schuchardt compared WM in two LD groups. The first group had “normal” intelligence scores and the other had “low” intelligence scores. Compared to controls, both groups of LD children displayed WM deficits. Similarly to the current findings, there were no differences in WM between the two groups of children with LD. The authors argued that WM deficits appear to constrain skill acquisition in reading and mathematics but are likely independent from intelligence (Gathercole et al., 2006; Maehler & Schuchardt, (2008). Both the Maehler and Schuchardt study and the results of the current investigation appear to corroborate with the argument that one’s level of intelligence may have little to do with the association between WM and LD.

Low WM vs. High WM on the WISC-IV. The second question sought to determine whether there were significant differences in WISC-IV psychometric profiles (VMI, PRI, PSI) of children with Below Average WMI Scores (Low WM = 89 or below) and children whose WMI scores fell in the Average to Above Average range (High WM = 90 or greater). All students in the sample were diagnosed with LD (both DLD and NDLD) and the two WM comparison groups were categorized on the basis of WMI scores alone (Due to the results of the first question a decision was made that none of the subsequent questions necessitated groupings based on DLD and NDLD). An ANOVA was run on the WISC-IV

VCI, PRI, and PSI and significant differences were found on the PRI score. No significant differences were found on the VCI or the PSI scores.

The results of the second analysis indicate that two groups of students with LD with high and low WM scores could be differentiated on the WISC-IV PRI. Although no studies were located that could directly compare the current findings, they are interesting because the WMI is not typically associated with the PRI or its subtests. However, significant differences were found between the High and Low WM groups on the VCI, PRI, and the PSI when the FS score was factored out.

The PRI is comprised of the Block Design, Picture Concepts, and Matrix Reasoning subtests and reportedly measures ability to think with visual images and manipulate them with fluency, cognitive flexibility, and the ability to form abstract concepts (Sattler, 2008). The WMI is comprised of the Digit Span and Letter-Number-Sequencing subtests and reportedly measures working memory, short-term memory, encoding ability, auditory processing skills, and cognitive flexibility (Sattler, 2008). The WISC-IV manual states that Letter-Number-Sequencing is related to verbal abilities and thus correlates highly with the VCI subtests (Wechsler, 2003). The WMI subtests correlate most highly with each other and next with the VCI subtests. Sattler (2008) reported that the Digit Span subtest has a moderately low correlation (r = .42) with the PRI and that Letter-Number-Sequencing also has a moderately low correlation (r =.48) with the PRI.

One reason that the current findings may not be in keeping with the correlational studies cited in the WISC-IV manual or by Sattler (2008) is because the sample groups in these studies were drawn randomly from the general population. In comparison, all participants in the current investigation presented with LD and were drawn from a clinical population. One therefore cannot draw direct comparisons between these results Nevertheless, it would likely be beneficial for researchers to further explore this area.

The WISC-IV manual does, however, list validity studies with special groups including children with learning disorders (reading, written expression, and math disorders). Although the RD group displayed the lowest WMI scores compared to students with written expression and math disorders, there was no statistical distinction between the mean VCI, PRI, WMI, and PSI performances across LD groups. However, caution must be used to interpret the WISC-IV special group findings as sample sizes are small (16-89 participants) and data were derived from independent settings where identical inclusion criteria and procedures for diagnoses could not be guaranteed.

Low WM vs. High WM on the WIAT-II. The second question determined that in the sample of LD students, students with Low WM and High WM could be differentiated on the WISC-IV PRI and when the FS score was factored out, Low WM and High WM could be differentiated on all three index scores (VCI, PRI, PSI). To further dissect the influence of WM on LD, the next question sought to determine whether there were differences in WIAT-II achievement profiles of children with Low WMI scores (89 and below) and High WMI scores (90 and above). An ANOVA was conducted and results indicated that there were significant differences on four WIAT-II subtests (Word Reading, Reading Comprehension, Pseudoword Decoding, and Numerical Operations).

In order to be sure that the findings were not influenced by intelligence (that is, as intelligence scores increase, achievement scores increase) it was necessary to partial out WM. This was accomplished by controlling the other WISC-IV Index scores. The analysis was run again but this time, the VCI, PRI, and PSI were controlled. Results of the ANCOVA indicate that significant differences exist between LD students with high and low WM in Word Reading, Reading Comprehension, Pseudoword Decoding, and Numerical Operations and these differences appear to be independent from the other WISC-IV Index scores.

These findings are in keeping with previous research as it has been well documented that students with LD often present with WM deficits. For example, WM deficits have been strongly linked to poor reading performance (e.g. Swanson & Siegel, 2001; Howe et al., 1999) and to poor mathematical performance (e.g. Bull & Johnston, 1997; Siegel & Ryan, 1989; Swanson, 1993). Gathercole et al. (2006) also reported that WM skills were significantly related to the severity of LD in both reading and mathematics. Similarly, Henry (2001) found that when compared to children with average abilities, those with more severe LDs had greater WM impairments. Although no causal effect can be derived from the current results, several researchers have argued that WM deficits appear to constrain skill acquisition in reading and mathematics and it seems to be independent from intelligence (Gathercole et al., 2006; Maehler & Schuchardt, 2009).

Utility of the WMI to differentiate LD subtypes. The next question examined whether the WMI could differentiate students with RD, MD, and GLD. This question was asked because the primary cognitive mechanisms that separate LD subtypes still remain unclear (Swanson & Jerman, 2006). The RD group consisted of students who scored below the 25th percentile on either the WIAT-II Reading Composite or on one or more of the reading subtests. The MD group consisted of students who scored below the 25th percentile on either the WIAT-II Mathematics Composite or on one or more of the mathematics subtests. The GLD group consisted of students who scored below the 25th percentile in both one or more reading subtests and one or more mathematics subtests. Results of the analysis indicated that there were no significant differences in WMI scores in any of the three LD groups. The results of the current study do not support the notion that LD groups can be separated on WM although this does not necessarily mean that WM cannot be used to differentiate LD subtypes. Rather, one can only infer that the WISC-IV WM measure is likely not a useful tool to separate RD, MD, and GLD.

Comparable studies in the literature had mixed results. Landerl et al. (2004) reported that there is no causal evidence that WM is a feature of MD. In a sample of first to fourth graders, however, Vukovic and Siegel (2010) found that MD could be characterized by deficits in math concepts and phonological decoding as well as some evidence for the involvement of WM, processing speed, and numerical reasoning.

Differentiating learning disability subtypes with other cognitive processes. The first four questions in the study were concerned with the role of the WISC-IV WMI on different LD groups. The final two questions explored whether other cognitive process differences could be found in RD, MD, and GLD. The overall psychometric profiles of the three LD groups were examined for differences. First, a one-way ANOVA was conducted to determine if there were any overall differences between RD, MD, and GLD on the basis four WISC-IV Index scores. Significant differences were found between the three groups on the VCI and PRI and marginal differences were found on the PSI. No differences were found on the WMI. To determine precisely where these differences existed a post hoc test was run. According to Tukey's HSD, specific differences were found between RD and GLD and between MD and GLD on the VCI. Significant differences were noted between RD and GLD on the PRI. Marginal differences were also noted between the RD and GLD on the PSI.

According to these findings, students with RD and MD may have similar VCI profiles but differ significantly from students with below average achievement in both reading and in mathematics. Students with MD and GLD as well as RD and MD had similar PRI profiles but students with RD and GLD had significantly different PRI profiles. Students with RD and MD had similar PSI profiles, but students with RD and GLD had significantly different PSI profiles. The results also suggest that children with low achievement in both reading and mathematics differentiate from RD and MD more often than RD is differentiated from MD.

Little has been published on WISC-IV correlates of academic achievement (Mayes & Calhoun, 2007). However, research on older versions of Wechsler's tests and other cognitive batteries have examined this relationship. For example, D'Angiulli and Siegel (2003) reported that RD and MD groups had significantly lower scores than typically achieving controls on the WISC-R verbal subtests. A study by Davis, Parr, and Lan (1997) examined the characteristics of LD in reading, spelling, and arithmetic via the Revised Woodcock-Johnson Psychoeducational Battery. The authors found that students with MD had weaker non-verbal skills than students with reading and spelling deficits. The students with both reading and spelling deficits had stronger nonverbal skills. Calhoun and Mayes (2005) reported that in a referred sample, students with neurological disorders (including LD) had lower PSI and Freedom from Distractibility (similar to the WMI) Index scores than VCI and POI scores on the WISC-III.

Despite these findings, the research is far from conclusive. Kavale and Forness (1984) found little evidence of distinct profiles of WISC and WISC-R scores in children with LD. Most studies that have used WISC or WISC-R patterns to diagnose LD have been either inconclusive or have not found significant differences in students with or without LD (D'Angiulli & Siegel, 2003). D'Angiulli and Siegel (2003) did find that RD and MD had significantly lower scores than a typically achieving group on WISC-R Verbal IQ subtests, although many typical achieving children showed this pattern as well. These authors concluded that performance patterns are not reliable enough for an LD diagnosis in individual children.

The last question of the study used logistic regression to predict membership in either RD or MD on the basis of the four WISC-IV Index scores (VCI, PRI, WMI, PSI). Overall, the four WISC-IV Index scores were able to correctly predict group membership almost 70% of the time. Group membership in the MD group was correct almost 75% of the time while group membership for the RD group was correctly predicted almost 65% of the time. This finding supports the notion that WISC-IV profile analysis may offer diagnostic utility.

Authors such as Sattler (2008) provide both statistical and clinical evidence of subtest attributes to interpret patterns of performance. Typical analyses comprise of a global interpretation of test scores, followed by interpretation of composite or index scores, then subtest clusters that may share common characteristics (Hale et al., 2007). There are, however, concerns about the reliability and validity of subtest analysis used in isolation although several authors support this practice for determining hypotheses about strengths and weaknesses and for developing interventions for specific needs (Hale et al., 2007).

Implications for Practice and Future Directions

The changing face of LD is a result of fundamental questions that are being asked about the exact nature of the disorder. As with any major change, uncertainty is the norm, not the exception, as it is in the LD field. Much of this uncertainty exists because questions still remain about whether there are processing differences between students with discrepant and non-discrepant LD (Meyers, 2000). Questions also remain about the cognitive processes that are responsible for subcategories of the disorder. Despite widespread criticism, the

IQ-achievement discrepancy model remains status quo both in theory and in practice (Klassen, 2002; Kozey & Siegel, 2008). With the exception of IDEA 04, most operational LD definitions continue to require a discrepancy between intellectual ability and achievement. Although considerable variation in LD definitions still exist, in Canada at least, there does appear to be some evidence of a more mainstream understanding of LD, primarily based on the Learning Disabilities Association of Canada (2002) recommendations (Kozey & Siegel, 2008).

In recent years, it does appear that the psychological community is at least willing to consider other methods of identification although there is a hesitation to embrace wholesale change. With regards to an operationalization definition of RD, a large survey of school psychologists endorsed response to intervention, cognitive processing, and phonemic awareness as RD components. The same survey found that a majority of school psychologists still endorsed use of an IQ-achievement discrepancy criterion (Machek & Nelson, 2007). Similarly, a survey of West Australian school psychologists found that most psychologists in this region still ascribe to a traditional definition of LD (Klassen, Neufeld, & Munro, 2005).

Although an increasing number of researchers attest that there is little convincing evidence that IQ discrepant students are different from other forms of underachievement (e.g. Fletcher, Morris, & Lyon, 2006), the discrepancy problem still seems to be the most significant issue in the LD field today. As such, more research exploring different variables that may or may not differentiate these groups needs to be conducted. It appears that the psychological community is either unsure or unwilling to abandon the discrepancy method without a lot of evidence. Secondly, the psychological processes related to different LD subtypes still need to be explored. If there is ever going to be a method of directly diagnosing LD, there is still much work to be done in terms of identifying and understanding the underlying cognitive processes involved in the disorder. With regards to the current research questions, it would be interesting to explore these questions again with a control group and with a stronger measure of WM.

Much of the previous research on WISC-III profiles of children with LD are difficult to interpret due to methodological inconsistencies. This is often due to researchers' use of incomplete test batteries resulting in compromised WISC-III factor scores; varying criteria for determining the presence or absence of LD; variations in LD sample size; and the use of different factor analytic methods (Filippatou, Dimitropoulou, & Sideridis, 2009). It will be important for future researchers to avoid these shortfalls as much as possible so that quality data can be analyzed and applied in practice.

Results of the current investigation are in keeping with the findings of researchers such as Swanson, Siegel, and Stanovich who argue that the education system should do away with discrepancy-based diagnosis of LD. This is not to suggest that IQ testing has no place in the educational decision making process. Rather, a greater emphasis should be placed on determining individual strengths and weaknesses as well as to rule out mental retardation.

Study Limitations

There are several limitations of this study that should be noted. The most significant limitation of this study is that the data was derived from a clinical, non-random population. This alone reduces the generalizability of findings greatly. Furthermore, because the data came from a secondary source, there were some limitations to what was known about the research subjects. For example, it was impossible to tell from the data set whether or not the subjects presented with co-morbid conditions. Also, the demographic information of the subjects was also somewhat limited. Because of this there may have been unknown confounding variables. Although inferences can be drawn from data of this sort, the applicability of findings to the general population is limited.

Another limitation to this study was that there was no typically achieving control group to compare results with. Having a control group would have added considerable depth to the meaning of the results by enabling the comparison to typically achieving students. Furthermore, this limitation made the interpretation of the findings somewhat more difficult to compare with existing studies because the majority of these do have a control group as a reference point.

Another issue was that some of the LD sample sizes that were formed for this study were smaller than anticipated. For example, the first question compared students with DLD and NDLD. It was surprisingly difficult to form a large group of students with DLD given the available data. Although it is not very likely that a larger sample would have yielded significantly different results, the results would have been more convincing. This issue could have also been addressed with a power analysis.

A final limitation of this study was the WM measure, the WISC-IV WMI, as it is primarily considered a “screener” for WM difficulties and does not assess the full scope of WM. Because the data came from a secondary source, there was no control over what assessment tools were used to collect the data. The WISC-IV WM subtests and WMI are not suited for isolating specific WM subcomponents (i.e. phonological loop, visual-spatial control pad, central executive), but from a clinical perspective these subtests do help determine if a more detailed WM assessment is warranted. As Leffard et al., (2006) pointed out, WISC-IV WMI subtests measure rehearsal and transformation of phonological information only and that the visual spatial sketchpad (from Baddeley’s model) is not adequately assessed in the main test battery. Due to this limitation, caution must be exercised in interpreting the results as they pertain to WM. Nevertheless, it was still important to investigate the relationship between the WMI and LD because of its widespread use in clinical practice. Researchers who wish to explore these questions further may want to consider using a more thorough measure of WM.

Conclusion and Summary

This study compared the role of cognitive processes in children diagnosed with LD through the traditional aptitude-achievement discrepancy model with students diagnosed on the basis of their low achievement alone. A secondary objective of this study was to determine whether identifiable differences exist between the cognitive profiles of students diagnosed with RD and mathematics disability MD and whether the WISC-IV WMI can be used to differentiate between various categories of students with LD.

The current study revealed that the WISC-IV WMI score could not be used to differentiate between DLD and NDLD students. When children with LD presented with low WMI scores, no differences could be found on either VCI or PSI scores when compared to students with LD with average or higher WMI scores. However, a significant difference was noted on the PRI. Students with RD, MD, and GLD, could not be differentiated on the WMI alone. The investigation also found evidence that students with low WM scores and high WM scores could be differentiated on the WIAT-II Word Reading, Reading Comprehension, Pseudoword Decoding, and Numerical Operations subtests. High and low WM scores could not differentiate RD, MD, or GLD. Other cognitive process, represented by the WISC-IV VCI, PRI, and PSI, could be differentiated by the three LD subtypes. Finally, group membership in RD and MD could successfully be determined on the basis of the four WISC-IV Index scores (VCI, PRI, WMI, and PSI).

The results of this research are in keeping with the growing body of evidence suggesting that there are few differences between students with DLD and NDLD. Although WM has been identified as a process strongly linked to LD, the WISC-IV WMI does not appear to be useful in differentiating LD subtypes. The results of this study do suggest that other WISC-IV Index scores such as the VCI, PRI, and PSI may be useful in differentiating between students with different LD subtypes.

In conclusion, the results of this study support the notion that diagnosing LD on the basis of discrepancy may not be an effective means of determining who qualifies for educational support services. Rather, a greater emphasis should be placed on using psychological test results for determining individual strengths and weakness as well as individually tailored interventions.

It would seem then that if educators and psychologists were to rely more on IQ/psychological testing for obtaining information for intervention rather than to meet some arbitrary criteria for funding, more students would likely qualify for assessment services and assistance. In terms of funding, it is this researcher's opinion that resources should be allocated on the basis of students' overall educational needs rather than meeting some pre-established discrepancy criteria that may or may not change from one school jurisdiction to another. It also seems that allocating resources on the basis of overall educational need is more in keeping with the sprit of inclusiveness. Nevertheless, the utility of the discrepancy method will likely continue to be debated for quite some time.

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Appendix A

The DSM-IV-TR defines LD as follows:

> "Learning disorders are diagnosed when the individual's achievement on individually administered, standardized tests in reading, mathematics, or written expression is substantially below that expected for age, schooling, and level of intelligence. The learning problems significantly interfere with academic achievement or activities of daily living that require reading, mathematical, or writing skills. A variety of statistical approaches can be used to establish that a discrepancy is significant. Substantially below is usually defined as a discrepancy of more than 2 standard deviations between achievement and IQ. A smaller discrepancy between achievement and IQ (i.e., between 1 and 2 standard deviations) is sometimes used, especially in cases where an individual's performance on an IQ test may have been compromised by an associated disorder in cognitive processing, a comorbid mental disorder or general medical condition, or the individual's ethnic or cultural background. If a sensory deficit is present, the learning difficulties must be in excess of those usually associated with the deficit. Learning Disorders may persist into adulthood."

Appendix B

ICD-10 Diagnostic Criteria (World Health Organization)

The World Health Organization has published diagnostic criteria in the ICD-10, which is another medical perspective. These criteria are outlined below:

F81 **Specific developmental disorders of scholastic skills**

Disorders in which the normal patterns of skill acquisition are disturbed from the early stages of development. This is not simply a consequence of a lack of opportunity to learn, it is not solely a result of mental retardation, and it is not due to any form of acquired brain trauma or disease.

F81.0 **Specific reading disorder**

The main feature is a specific and significant impairment in the development of reading skills that is not solely accounted for by mental age, visual acuity problems, or inadequate schooling. Reading comprehension skill, reading word recognition, oral reading skill, and performance of tasks requiring reading may all be affected. Spelling difficulties are frequently associated with specific reading disorder and often remain into adolescence even after some progress in reading has been made. Specific developmental disorders of reading are commonly preceded by a history of disorders in speech or language development. Associated emotional and behavioural disturbances are common during the school age period.

"Backward reading"
Developmental dyslexia
Specific reading retardation

Excludes: alexia NOS (R48.0)
dyslexia NOS (R48.0)
reading difficulties secondary to emotional disorders (F93.-)

F81.1 **Specific spelling disorder**

The main feature is a specific and significant impairment in the development of spelling skills in the absence of a history of specific reading disorder, which is not solely accounted for by low mental age, visual acuity problems, or inadequate schooling. The ability to spell orally and to write out words correctly are both affected.

Specific spelling retardation (without reading disorder)

Excludes: agraphia NOS (R48.8)
spelling difficulties:
· associated with a reading disorder (F81.0)
· due to inadequate teaching (Z55.8)

F81.2 Specific disorder of arithmetical skills

Involves a specific impairment in arithmetical skills that is not solely explicable on the basis of general mental retardation or of inadequate schooling. The deficit concerns mastery of basic computational skills of addition, subtraction, multiplication, and division rather than of the more abstract mathematical skills involved in algebra, trigonometry, geometry, or calculus.

Developmental:
· acalculia
· arithmetical disorder
· Gerstmann's syndrome

Excludes: acalculia NOS (R48.8)
arithmetical difficulties:
· associated with a reading or spelling disorder (F81.3)
· due to inadequate teaching (Z55.8)

F81.3 Mixed disorder of scholastic skills

An ill-defined residual category of disorders in which both arithmetical and reading or spelling skills are significantly impaired, but in which the disorder is not solely explicable in terms of general mental retardation or of inadequate schooling. It should be used for disorders meeting the criteria for both F81.2 and either F81.0 or F81.1.

Excludes: specific:
· disorder of arithmetical skills (F81.2)
· reading disorder (F81.0)
· spelling disorder (F81.1)

F81.8 Other developmental disorders of scholastic skills

Developmental expressive writing disorder

F81.9 Developmental disorder of scholastic skills, unspecified

Knowledge acquisition disability NOS
Learning:
· disability NOS
· disorder NOS