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Curriculum Based Measurement and Cognitive Assessment Predictions on Reading Outcomes: A Meta Analysis

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CURRICULUM BASED MEASUREMENT AND COGNITIVE ASSESSMENT PREDICTIONS ON READING OUTCOMES: A META ANALYSIS

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Title: Curriculum Based Measurement and Cognitive Assessment Predictions on Reading Outcomes: A Meta Analysis

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This meta-analysis is a review of how curriculum based measurement (CBM), short-term memory, and processing speed, relate to both basic reading skills and reading comprehension. This was developed due to the debate in the field of school psychology on the utility of using cognitive measures as important and relevant variables in the identification of learning disabilities. The goal of this study was to determine the strength of association of these variables to reading abilities and to determine if the strength of association between curriculum based measurement differed significantly from short-term memory and processing speed when compared to reading.

In order for studies to be included, they must have met several criteria, including: Publication on or after 1990, participants must have been between the ages of 4 and 14, outcome measures must have been one of the Woodcock reading or tests of achievement, and reliabilities of measures must have exceeded .70.

Each predictor variable was compared to both basic reading skills and reading comprehension to determine strength of association (effect size). Finally, the short-term memory and processing speed variables

were combined to create a “cognitive processing” moderator variable to compare strengths of association between CBM and cognitive processing when predicting reading.

The results indicated large effect sizes ranging from .618-.636 for CBM when predicting basic reading and reading comprehension. Moderate effect sizes ranging from .387-.433 were obtained when comparing short-term memory and processing speed to both basic reading and reading comprehension. CBM showed a significantly ($p<.05$) greater effect to basic reading than cognitive processing when sample size was controlled, although there was not a significant difference when this comparison was made to reading comprehension.

Limitations of the study included the breadth of narrow abilities under the terms “short-term memory” and “processing speed”, exclusion of other important variables (such as sex or whether one had a disability) when determining reading skills, narrow parameters of allowable tests, no independent coders used for the analysis, and a narrow focus on reading for this study. The implications of these findings to school psychology are discussed.

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CHAPTER I

INTRODUCTION

Overview

The passage of the No Child Left Behind Act (NCLB) has placed increasing pressure on various school districts to ensure that all students will demonstrate competence in reading, writing, and math (U.S. Department of Education, 2001). However, the magnitude of children with various learning concerns continues to be an ever-increasing issue (Individuals with Disabilities Education Improvement Act, 2004) (hereinafter known as IDEA, 2004), particularly during this time when NCLB requires success for all students.

Although the mandates indicated by the NCLB law are still relatively young, the mission of school districts to identify and intervene for struggling learners has been a part of the educational system for over a century and has also been a focal point for school psychologists (Fagan & Sachs Wise, 2000). One of the most prominent roles of the school psychologist is to engage in individual evaluation to help determine if a student might present with an educationally disabling condition. Although there are potential disabilities that could be unearthed with a multi-disciplinary evaluation, the assessment for learning disabilities continues to be an area where school psychologists spend much of their time and effort (Reschly & Ysseldyke, 2002). Although the identification of and intervention for students with learning problems have been prominent themes for many years, the importance of early identification and intervention for learning problems, in these times of high accountability, are presently areas of intense focus (Jacob & Hartshorne, 2007).

Statement of the Problem

Although the assessment for the presence of learning disabilities takes a great deal of the school psychologist's time, there is little agreement on how this should be done. Historically, the federal guidelines have focused on the presence of a severe discrepancy between expected and actual achievement should be present to determine if a student presents with a learning disability (Individual with Disabilities Education Act, 1997). However, the passage of the Individuals with Disabilities Education Improvement Act (2004) has made the criteria for identification more nebulous. According to the regulations, it is indicated that no district *shall be required* to determine if a student presents with a severe discrepancy (emphasis added). The regulations further indicate that a district *may permit* the use of a Response to Intervention framework as part of the learning disability eligibility determination process (emphasis added) (IDEA, 2004).

Use of Curriculum Based Measurement as the Sole Modality to Determine a Specific Learning Disability

Although there have been problems with the use of ability-achievement discrepancies to determine learning disabilities (Reschly & Yssledyke, 2002; Brown-Chidsey & Steege, 2005) and the flexibility of the regulatory language allows for varied practices on determining learning disability eligibility, this paradigm change has engendered more inconsistency and, subsequently, fierce debate on what should be done to document the eligibility process. There are some who espouse a purely “Response to Intervention” framework, which holds that empirically based intervention practices and formative assessment measures are sufficient to document the presence of a disability (Reschly & Yssledyke, 2002; Reschly, 2005).

According to Shinn (2007), the notion of RTI, with Curriculum Based Measurement (CBM) as the main tool to conduct this, is discussed. He notes, “A RTI process can be used only as a replacement process for ability-achievement discrepancies in the special education eligibility procedure. That is, students can be referred, tested, albeit on some different dimensions, and placed in special education” (p. 610). Shinn further discusses use of the three-tiered model to provide effective remedial interventions. He further highlights the importance of CBM in the RTI process, noting, “Integral to this RTI conception is the use of CBM in a three-tier model in a way that combines universal screening and progress monitoring" (p. 611).

Although most researchers stop short of identifying that CBM or RTI should be the only method used to identify learning disabilities, the downplay of the importance of cognitive or neuropsychological assessment is noted in the literature. According to Fletcher, Coulter, Reschly, and Vaughn (2004):

> Regardless of whether cognitive processing is conceptualized as a modality (visual or auditory), intact and deficit neuropsychological functions, successive or simultaneous processing, or the many variations of learning style, there is little data source showing that either teaching the cognitive processes produces better achievement or that matching instruction to cognitive processing strengths leads to better achievement (Kavale & Forness, 1999) (pp. 320-321).

Although the premise of the aforementioned paragraph is more with intervention than the relationship between various assessment measures and achievement, the downplay of cognitive assessment as important to achievement is also highlighted. Fletcher et al. (2004) further note, "Moreover, students with LD in different academic areas can be differentiated on cognitive and brain function assessments, and even in the heritability of reading and math disorders (Grigorenko, 2001;

Lyon, et al., 2002)” (p. 317). This suggests an acknowledgement of the importance of cognitive and neuropsychological characteristics despite the recommendation against use of these instruments.

Use of Cognitive or Neuropsychological Factors to determine a Specific Learning Disability

There are others who indicate that although Response to Intervention is favorable, there should nevertheless be an individual evaluation consisting of measures that document psychological processes (Hale, Kaufman, Naglieri & Kavale, 2006; Hale & Fiorello, 2004; Semrud-Clikeman, 2005; Miller 2007). These researchers highlight the relationships of cognitive and neuropsychological functioning to reading, writing, and math. There are yet others who seek a compromise by only assessing academic achievement (Fletcher, 2008).

When the final IDEA 2004 regulations were published in August 2006, it was determined that a comprehensive evaluation was required as part of the eligibility process for the identification of learning disabilities (Posny, 2007). Again, the role of cognitive assessment in the establishment of learning disabilities has been hotly debated, even with the mandate of a comprehensive evaluation occurring before the identification of a learning disability. According to Reschly (2008), although admitting that a comprehensive evaluation is required to determine disability eligibility, maintains that cognitive assessment should only be reserved for the establishment of mental retardation. Meanwhile, Gresham, Restori, and Cook (2008) have argued that the only cognitive process that has any impact on reading is auditory processing. In fact, Gresham et al. convey, "the authors of the current article do not conclude that RTI and cognitive testing are compatible for SLD identification" (p. 7).

These studies tend to suggest that a Response to Intervention (RTI) framework is favorable as a first step among students with learning concerns. The disagreement, however, is over what should occur as part of the comprehensive evaluation. Indeed, if the assessment process were to end short of a thorough evaluation, including cognitive and/or neuropsychological assessment, then it should be stated with confidence that the cognitive or neuropsychological assessment adds little diagnostic utility to the learning disability identification or intervention process.

Despite the claims by many that cognitive assessment does not add diagnostic utility (e.g.Reschly & Yssledyke, 2002; Reschly, 2005; Gresham, Restori, & Cook, 2008), others disagree. Hale et al. (2006) provide a specific case study where identification of specific cognitive variables related to not only correctly assessing a child's problem, but also informing the correct intervention. Hale et al. note that using RTI alone would not have been satisfactory in correctly identifying the problem or intervention.

There also has been much written on the importance of engaging in neuropsychological assessment when assessing for learning concerns. According to Miller (2007), a school neuropsychological assessment should be required for:

- A child who is not responding to multiple intervention strategies.
- A child with evidence of processing deficiencies on a psychoeducational evaluation.
- A child with a valid large scatter in psychoeducational test performance.
- A child with a known or suspected neurological disorder.
- A child with a history of a neurodevelopmental risk disorder.
- A child returning to school after a head injury or neurological insult.
- A child who has a dramatic drop in achievement that cannot be explained. (p. 63)

Breiger and Majovski (2008) also focus on the importance of a neuropsychological assessment, even in this era of RTI. They comment specifically, “The results of neuropsychological assessment potentially provide valuable information that can be used to identify the presence of learning disabilities and develop intervention recommendations. Information from a neuropsychological can be used to support the development of a well-articulated model of the child's development of academic skills" (p. 153).

Clearly, there has been disagreement about the utility of cognitive or neuropsychological assessment and their use in the identification of and intervention for learning disabilities. Therefore, further research is needed to determine the relationship of these cognitive and neuropsychological assessments cognitive and neuropsychological to determine if they provide any "value added" information above and beyond formative assessment techniques to inform the diagnosis of learning disabilities.

Problem Significance

Accurate and comprehensive identification of and intervention for students with learning disabilities continues to develop with respect to importance. One must be wary to assume a learning disability is present when other problems could be interfering (such as social-emotional concerns).

The federal regulations (Individual with Disabilities Education Improvement Act, 2004) currently identify the following areas as those that can be affected by learning disabilities:

- Basic Reading Skills
- Reading Fluency
- Reading Comprehension

- Math Calculation
- Math Problem Solving
- Written Expression
- Listening Comprehension
- Oral Expression

It is of paramount importance that the research is substantial with respect to construct validity in each of these areas to ensure that accurate identification of learning disabilities is to occur.

Purpose of the Study

Given the debate about the best way for learning disabilities to be identified, it is important to determine if cognitive or neuropsychological characteristics demonstrate relationships to overall skills with academic achievement. Therefore, it is important to determine the relationship of CBM to reading as well as the aforementioned cognitive/neuropsychological assessments to reading to determine if those assessments provide “value added” information to reading ability. The purpose of this study is to analyze the data from existing studies and compare the relationships of Curriculum Based Measurement (CBM), short-term memory, and processing speed on outcomes in basic reading skills and reading comprehension. Although there are several domains of cognitive processing, short-term memory and processing speed were selected given their documented relationship to reading (Mather & Wendling, 2005; Flanagan, Ortiz, Alfonso, & Mascolo, 2006).

This can be done through review of past studies to synthesize past results, also known as a meta-analysis. According to Lipsey and Wilson (2001), “The term *meta-analysis* has come to encompass all of the methods and techniques of quantitative research synthesis developed by these and other researchers” (p. 1). Lipsey and Wilson also add that the research studies are the samples used in a meta-analysis and “the resulting data are then analyzed using special adaptions of conventional statistical techniques to investigate and describe the pattern of findings in the selected set of studies” (p. 2). According to Kavale and Glass (1981), use of a meta-analysis defends against problems related to other methods of reviewing past studies. For example, using what is known as narrative review, a technique where verbal reports of past studies are proffered, often result in ad hoc elimination of studies that do not fit the reviewer’s conceptualization of what should be included. Using box-score analysis, a technique where studies receive a “point” for studies that reach statistical significance, does not control for the differing characteristics between studies that can significantly affect significance (such as sample size). As can be seen, a different technique is needed to address the shortcomings of the aforementioned techniques. Meta-analysis provides a logical solution. Meta-analysis utilizes statistical results and, using techniques similar to other studies, transforms them to similar metrics for comparison.

This study proposes to show the association between CBM and reading and to compare this with the constructs of both short-term memory and processing speed to reading. This study limited the outcome measures to those measuring basic reading skills and reading comprehension. Math calculation and math problem solving were excluded because there is currently a lack of research relating CBM measures to either math problem solving or math computation on normative standardized assessments. According to Thurber, Shinn, and Smolkowski (2002), “A relation with commercial norm-referenced math tests provides only modest support for validity” (p. 499). Furthermore, a search of the databases of Academic Search Complete, PsychINFO, PsychARTICLES, and the Psychology and Behavioral Sciences Collection generated only 53 hits when the terms “curriculum based measurement” and “math” were entered as keywords. Of those 53 hits, only two used individualized standardized normed reference tests.

Listening comprehension and oral expression were also omitted given the lack of research in CBM or measures related to these constructs. A search of the databases of Academic Search Complete, PsychINFO, PsychARTICLES, and the Psychology and Behavioral Sciences Collection generated zero hits when the terms “curriculum based measurement” and either “listening comprehension” or “oral expression” were entered. When the term "CBM" was used, zero hits were generated with the term "oral expression" and one hit was generated with the term "listening comprehension" entered as keywords. Written expression was omitted because the construct of written expression is so broad given that it encompasses writing fluency, organization, sentence structure, mechanics, and vocabulary. Using a single unitary construct (written expression) does not well-discriminate the specific nature of a problem that a child could have. Reading fluency was omitted because most CBM measures are measures of fluency and there are currently few normative instruments that measure reading fluency as a separate construct. This was determined by a search of the PsychINFO, PsychARTICLES, Academic Search Complete and Behavioral Sciences Collection databases, where the searches of CBM, curriculum based measurement, WJ, GORT (Gray Oral Reading Test), and KTEA (Kaufman Test of Educational Achievement) led to only two articles. Given the sparse number of studies correlating CBM to reading fluency from a normative instrument, this construct will not be measured.

In addition, only a few cognitive/neuropsychological variables were explored. Although there are a variety of neuropsychological factors which have been associated with achievement outcomes (e.g. executive functions such as inhibition control and planning (Naglieri & Johnson, 2000)), it is important to note that an initial exploratory analysis of the problem solving literature has demonstrated results that differ in scope from the nature of this study. Many studies look at mean differences between populations that have problems with certain neuropsychological skills, such as executive functioning, on outcome variables (ex. Roodenrys, Koloski, & Grainger, 2001), or look at multiple regression to determine the extent these independent variables relate to the dependent variables (ex. Altemeier, Jones, Abbott, & Berninger, 2006) while the scope of this study is aimed at comparing concurrent and predictive validity on observed variables.

As a result of the aforementioned research, the variables which were explored in addition to CBM include short-term memory and processing speed. These constructs were selected for several reasons: Both short-term memory and processing speed have shown significant overlap with cognitive assessment and neuropsychological assessment. Most contemporary cognitive assessments explore both processing speed and short-term memory as germane to both overall cognitive ability (Wechsler, 2002; Woodcock, McGrew, & Mather, 2000) and academic achievement (Flanagan, Ortiz, Alfonso, & Mascolo, 2006; Mather & Wendling, 2005; Flanagan & Mascolo, 2005). Short-term memory also has a history with neuropsychology. The term *working memory* has been indicated as highly important for executive functions to take place (Hale & Fiorello, 2004).

Processing speed not only is often assessed by measures of cognitive assessment, but also has been indicated in the neuropsychological literature. For example, the coding subtest of the Wechsler scales has been noted to be an important part of the diagnostic process in Reitan's interpretative sequence for neuropsychological problems (Reitan & Wolfson, 1992; Hale & Fiorello, 2004). According to Reitan and Wolfson (1992), "The Coding subtest of the WISC-R is essentially similar in requiring an integration of left and right cerebral functions. Both of these tasks also require efficiency of performance for a successful solution" (p. 116). Furthermore, speed of processing is often measured as an important dimension in tests of executive function. For example, the Delis Kaplan Executive Function System (Delis, Kaplan, & Kramer, 2001) combines visual scanning, sequencing ability, and processing speed, as important factors in their trail making test.

Another reason for the selection of these variables is the availability of correlations of these constructs to academic achievement. One particular test, the Woodcock Johnson Tests of Cognitive Ability-3rd Edition (WJ-III) (Woodcock, McGrew, & Mather, 2001) has comparisons available of these important constructs. In fact, all children in their data sample took both the cognitive and achievement tests, allowing for very strong internal validity.

A final reason to look more closely at measures of short-term memory and processing speed is that have been shown to be predictive of reading ability but not necessarily to overall 'g', which is also known as general intelligence. The concept of ‘g’ has a long history. According to Wasserman and Tulsky (2005), Charles Spearman conceptualized the ‘g’ factor in 1904. He did this by analyzing the shared variance between different cognitive tests. As a result, Spearman derived the factors of ‘g’ for general common variance across measures, and specific unique variance known as ‘s’. Although controversial, this has been heralded by many researchers. This included David Wechsler, despite his orientation in looking at specific capabilities exhibited by individuals on intelligence tests.

There has been significant research relating ‘g’ to achievement. For example, the idea of using ‘g’ as the metric to which one should “expect” someone to perform at for achievement has been a long standing approach. Shaywitz (2003) remarks on this, indicating, “Traditionally, the concept of dyslexia as an “unexpected” difficulty in reading was interpreted as underachievement in reading relative to ability (or learning potential). This was based on the belief that in the average person, ability (as measured by IQ) and reading achievement are very closely correlated. In other words, simply knowing a person’s IQ should have predicted his level of reading achievement” (p. 136). Other research has related interventions as successful related to ‘g’ (ex. Fuchs & Young, 2006). However, not all areas measured by intelligence tests are “highly g loaded” (in other words, has shown a great deal of contributing variance to ‘g’) yet has a history of relating to achievement.

Processing speed, for example, has a history of a weaker relationship to ‘g’ (Flanagan, 2000; Woodcock, McGrew, & Mather, 2001; McGrew, Flanagan, Keith, & Vanderwood, 1997; Keith, 1999; Rattan, 1992.) Despite the information that has not related processing speed as a significant predictor to ‘g’, it has been associated with learning problems (Mather & Wendling, 2005; Urso, 2008; Sujansky, Griffith, & Rattan, 1990). Therefore, this study may provide further information related to looking beyond a single unitary construct (g) and at more factors that contribute specifically to learning disabilities.

Research Questions

1. What is the overall effect size when using CBM to predict basic reading skills?
2. What is the overall effect size when using CBM to predict reading comprehension skills?
3. What is the overall effect size when using short-term memory to predict basic reading skills?
4. What is the overall effect size when using short-term memory to predict reading comprehension skills?
5. What is the overall effect size when using processing speed to predict basic reading skills?

6. What is the overall effect size when using processing speed to predict reading comprehension skills?
7. What are the effect sizes of short-term memory and processing speed when they are grouped as “cognitive” and “CBM” variables when used to predict basic reading skills?
8. What are the effect sizes of short-term memory and processing speed when they are grouped as “cognitive” and “CBM” variables when used to predict reading comprehension?

Hypotheses

1. It is hypothesized that CBM will show a mild positive effect size over cognitive or neuropsychological measures in predicting outcomes in basic reading skills. This is based on the logical assumption that outcome measures will correlate better to outcome measures than related processing measures. However, it is also hypothesized that associations between the cognitive variables of interest (short-term memory and processing speed) will still show positive effect sizes with associations to basic reading skills given the exploratory findings of the initial problem solving research.
2. It is hypothesized that CBM will show a mild positive effect size over cognitive or neuropsychological measures in predicting outcomes in reading comprehension. This is based on the logical assumption that outcome measures will correlate better to outcome

measures than related processing measures. However, it is also hypothesized that associations between the cognitive variables of interest (short-term memory and processing speed) will still show positive effect sizes with associations to reading comprehension given the exploratory findings of the initial problem solving research.

See Figure 1 for a logical path diagram of these hypotheses.

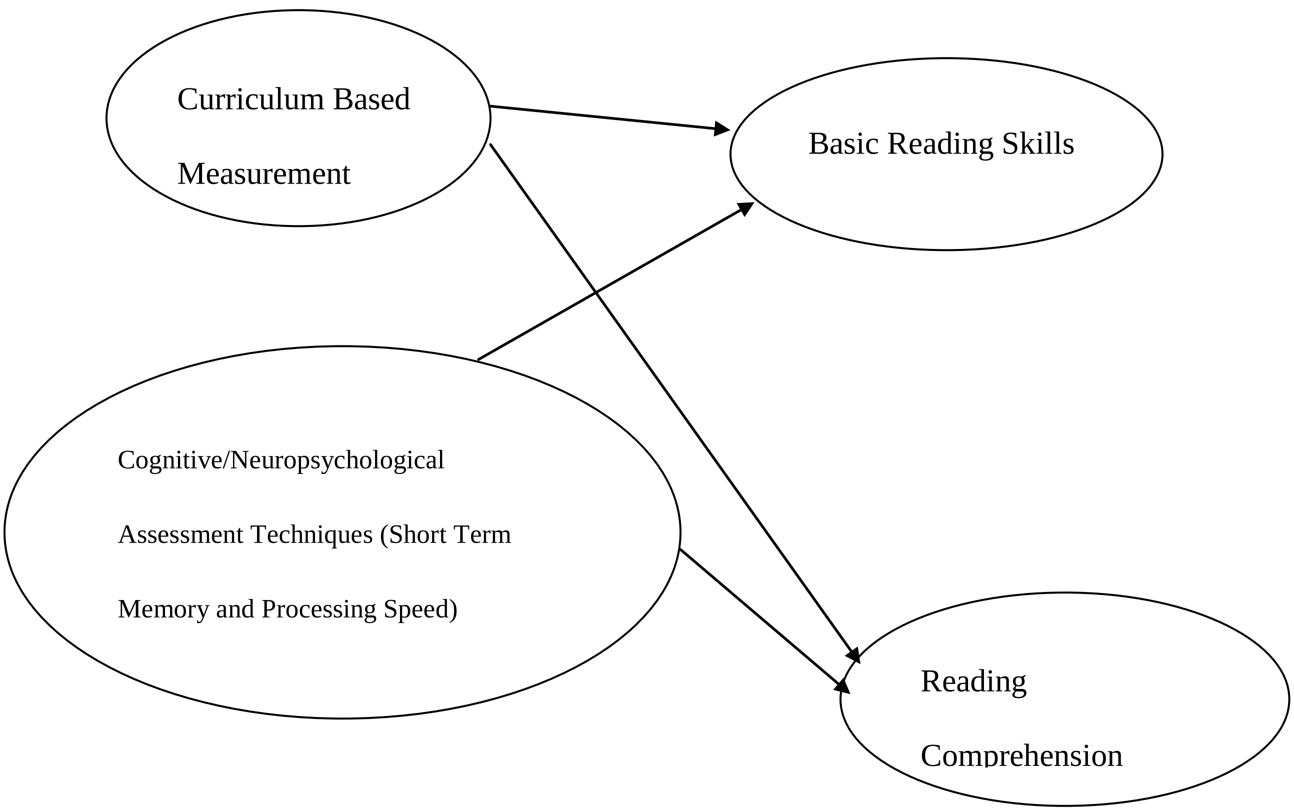

Figure 1. Logical path diagram of the latent variables.

Definitions

1. *Meta Analysis:* According to Gene Glass, as cited in Schulze (2004) it is the "Systematic process of quantitatively combining empirical reports to arrive at a summary and an evaluation of research findings" (p. 10).
2. *Curriculum Based Measurement:* According to Shinn (2002), curriculum based measurement is "a set of standardized and validated short duration tests that are used by special education and general education teachers for the purpose of evaluating the effects of their instructional programs" (p. 671).
3. *Short-Term Memory:* According to McGrew and Flanagan (1998), short term memory is "the ability to apprehend and hold information in immediate awareness and then use it within a few seconds" (p. 21). Constructs that measure both rote short-term memory (for example, being able to repeat a series of digits forward) and working memory (the ability to manipulate information in short-term memory, for example, reciting a series of digits backward) will be included under the overarching definition of short-term memory.
4. *Processing Speed:* According to McGrew and Flanagan (1998), processing speed is "the ability to fluently perform cognitive tasks automatically, especially when under pressure to maintain focused attention and concentration" (p. 24). Both visual-motor

processing speed (such as those measured by tasks such as "Coding" on the Wechsler tests) and rapid naming (such as those measured by tasks such as "Rapid Picture Naming" on the WJ tests) will be included under the overarching definition of processing speed.

5. *Outcome measures:* For the purposes of this study, outcome measures are the reading measures that serve as correlates to the curriculum based, cognitive, or neuropsychological predictor measures.
6. *Basic Reading Skills:* Basic Reading Skills stand for word identification and word attack skills. In other words, they represent the ability to which one can read words and sound out unknown words.
7. *Reading Comprehension:* Reading comprehension is defined as the meaning and understanding one derives from written text. Because of the restriction on tests, the reading comprehension techniques are all cloze procedures. In a cloze task, the examinee is given a passage with a missing word and the examinee must supply the missing word.

Assumptions

It is assumed that all studies selected for the analysis have followed best practice procedures for design implementation (which likely will be the case if the studies have been approved for publication.) Furthermore, it should be assumed that all studies that have been selected for analysis have met the predetermined criteria for inclusion.

Limitations

This study does present with some limitations. As is the nature of meta-analysis, the samples of the studies will differ with regard to age, number of participants, type of assessment, and date of assessment.

Another limitation of the study concerns the use of the outcome measures. To ensure that the latent skills (basic reading skills and reading comprehension) are strongly associated, only tests authored by Richard Woodcock will be used because of the similarity of task demands across his tests. Unfortunately, results on these instruments do not always generalize to the classroom environment. The demands of the various school curricula may be higher or lower than the normed population of the instruments might suggest. This needs to be taken into account as a threat to external validity.

The restriction of these tests also lends itself to another limitation. That is, that reading comprehension is assessed only through cloze reading. A cloze reading passage requires the student to read and supply words that are missing. Although cloze is a method to assess reading comprehension, it is not without its limitations. According to Unrau (2004), “Cloze tests tell us very little, if anything, about our students’ capacity for higher-order thinking in the form of interpretive or inferential comprehension” (p. 124). Because the reading of cloze passages is the only type of assessment used for reading comprehension in this study, the assessment of inferential comprehension skills is compromised.

Chapter II

LITERATURE REVIEW

Overview

The purpose of this chapter is to review several facets pertinent to the study. First, a review of the history and challenges of identifying learning disabilities will be discussed, given the relevance of this issue to the statement of the problem. Next, the relationships between curriculum based measurement and basic reading skills, as well as reading comprehension skills will be discussed. The following sections will overview the relationship of short-term memory to basic reading skills and reading comprehension. Next, the relationship between processing speed will be highlighted between basic reading skills and reading comprehension. Finally, a review of the process and literature related to the technique of meta-analysis will be discussed.

The Identification of Learning Disabilities: A Spirited Debate

The assessment for and identification of learning disabilities have served as regular functions of the school psychologist. Although the ability-achievement discrepancy has been used as a framework for identifying learning disabilities for many years, there have been significant concerns with this framework from both research and applied perspectives (Reschly & Yssledyke, 2002; Fuchs, Deshler & Reschly, 2004; Hale, Kaufman, Naglieri & Kavale, 2006; Brown-Chidsey &

Steege, 2005; Feifer & Della Toffalo, 2007). There is a degree of universal agreement about the shortcomings of the discrepancy approach.

One of the most significant shortcomings of the discrepancy approach was the “wait-to-fail” paradigm that often characterized learning disability assessments (Reschly & Yssledyke, 2002; Brown-Chidsey & Steege, 2005). Typically, children at early ages would be tested with the notion that a learning disability would occur if there were a significant difference between expected achievement (measured by an intelligence quotient) and actual achievement (measured by a norm-reference achievement test.) However, given that few young children read proficiently, a child at this age who fails every item on a reading test may not look severely dissimilar with same-aged peers. Dumont and Willis (2009) well-illustrate this phenomenon, humorously citing what a report might look like if a first grade child obtained raw scores of zero on all subtests of an achievement test. It was not until later when students with reading problems would have those difficulties show these difficulties on a norm-referenced test. By then, many children who did not “qualify” as learning disabled likely missed the necessary intervention that was needed in order to be successful.

Other problems were also inherent in the discrepancy approach. These include the inconsistency from state to state where policies differ somewhat on how to approach the identification of learning disabilities. Furthermore, there has been research to indicate that “slow learners” (those who have lower intelligence quotients and achievement scores) benefit from targeted services just as much as those who meet this profile of having a discrepancy (Reschly & Yssledyke, 2002).

Although there is agreement about why the ability-achievement discrepancy was a problematic method to the identification of learning disabilities, how exactly to identify learning disabilities has been a source of significant debate. One perspective is to use a strict framework of the problem-solving model (Tilly, 2002; Deno, 2002) as a basis for special education eligibility (Reschly & Yssledyke, 2002; Reschly, 2005). Indeed, Reschly & Yssledyke (2002) have argued:

> In Level IV problem solving classification of the student as needing special education may be considered based on documentation of (a) substantial discrepancies from average levels of classroom performance that (b) are not resolved to a sufficient degree by high quality interventions in general education, or behavioral discrepancies that (c) require programming elements or instructional intensity beyond the resources that reasonably can be provided in general education, and (d) there is a clear need for the kind of services provided in special education (p. 13).

Another component to identifying learning disabilities that has received considerable attention and debate are the disorders in one or more of the psychological processes. This component, although still a required part of IDEA (2004), continues to be an area of pointed debate. For example, at a debate on Response to Intervention (Shinn, 2005) sponsored by the American Psychological Association, the presentation indicated that a learning disability is not a processing issue because the state definition has been ignored for over 30 years, that most states ignore these classification criteria, 13 states do not provide explicit guidelines, and that there is a trend toward diminishing state specification of this criteria. This information failed, however, to indicate why processing is not a component of LD (indeed the law indicates it needs to be). Instead, it only relayed that LD wasn’t a processing disorder because states do not follow it.

Another criticism of viewing the importance of cognitive processes as an important part for special education eligibility is the lack of what is known as an Aptitude Treatment Interaction (or ATI). Reschly and Yssledyke (2002) discuss Cronbach’s research in seeking ATI’s and noted that there have been none. The framework of the ATI is that by knowing a subject’s unique assessment profile, programs could be built based on this combination. Again, the primary criticism is that such a framework has yet to be realized.

There are others who have specifically called into question the use of cognitive processing techniques related to learning disability identification. Reschly and Hosp (2004) explicitly state:

> Other features in future SLD classification criteria are far less certain. One controversial aspect is the role of intellectual ability and perceptual or cognitive processing. Several constituencies have significant vested interests in the continuation of some form of cognitive assessment (e.g.. Hale, Naglieri, Kaufman, & Kavale, 2004), although the fundamental fact remains that empirical relationships have not been established between assessment of perceptual or cognitive processes and improved accuracy in SLD identification, better control of SLD prevalence, and more effective instructional interventions for children with SLD. It is unfortunate if severe discrepancy is replaced by another equally controversial criterion without extensive validity studies, both evidential and consequential (p. 211).

Furthermore, Gresham et al. (2008) also maintain that cognitive assessment leads to little value added within a comprehensive evaluation. In fact, they indicate, “Although we would agree that years of rigorous research have established a clear relationship between phonological processing and reading, the same cannot be said of other cognitive processes and academic achievement” (p. 5).

Clearly there is a strong endorsement by some researchers to cull the construct of cognitive or neuropsychological processing from the identification of learning disabilities. An important component of this study will be to establish, or fail to establish, the validity of cognitive or neuropsychological processing to achievement outcomes.

Although there are some who indicate that the assessment of cognitive or neuropsychological processes should be unrelated to learning disability eligibility, others have indicated that the assessment of these processes is a necessary component to LD eligibility. An article by Semrud-Clikeman (2005) specifically addressed the importance of addressing neuropsychological aspects for learning disabilities, including working memory, speed of information processing, and executive function. Specifically for working memory, Semrud-Clikeman maintains, “To decode words, the child’s working memory must be functional and allow the child to retain a “template” of the letters until the word is sounded out” (p. 565). For speed of information processing, Semrud-Clikeman noted that speed of information processing “separates fluent readers from non fluent readers” (p. 564). Executive functions help a child to “evaluate his or her performance, and they also inhibit response to irrelevant stimuli” (p. 565).

Hale and Fiorello (2004) also identify the criticism of the lack of aptitude treatment interactions (ATIs) (Reschly & Yssledyke, 2002). Specifically, they comment:

> As Braden and Kratochwill (1997) have noted, however, the fact that ATIs weren't established in the past doesn't mean that they can't be established in the future, especially at the single-subject level of analysis. Changing the focus from the *content* of test items (e.g. auditory, visual) to the underlying psychological *processes* (Reynolds, Kamphaus, Rosenthal, & Hiemenz, 1997) may be the key to understanding the true nature of brain-behavior relationships for individual children (p. 40).

As can be seen, a potential key to progressing toward ATI establishment is to redefine the construct of what has been seen. In other words, the solution may not be what is in the modality of presentation is, but rather the neuropsychological processes that occur during the learning process.

Furthermore, despite the criticisms of Reschly and Yssledyke (2002) and Gresham et al. (2008), related to the failure of ATIs to be present, it bears mentioning that ATIs have indeed been revealed in the problem solving research. For example, a study by Fuchs and Young (2006) found that overall *g* (general intelligence or general cognitive ability) was a significant factor on the effectiveness of an intervention for reading comprehension. Naglieri and Johnson (2000) found an impact of a math calculation intervention related to the performance of the planning factor on the Cognitive Assessment System (Naglieri & Das, 1997). A study by Altemeir et al. (2006) revealed that certain cognitive profiles related to how well certain third and fifth graders would be able to effectively use notes in order to write.

Other researchers have noted that the move away from assessment of cognitive processes can have deleterious effects. Hale, Kaufman, Naglieri, and Kavale (2006) discuss eligibility determination as requiring *both* RTI and individualized assessment when a child has failed to respond. They cite a specific case study where, on the surface, the child seemed to present with a certain type of learning problem and was subsequently treated. After a thorough assessment, it was determined that the neuropsychological processes impacted were dissimilar from the working hypothesis and that he, instead, presented with a right hemisphere learning dysfunction. A new intervention was tried after the assessment, which subsequently adequately addressed the child’s concerns. Hale and Fiorello (2004) also cite a case study where a student showed a severe decline in overall cognitive functioning in a child during an independent evaluation after the school decided not to do a comprehensive reevaluation. After an independent evaluation, which showed serious decline in cognitive and academic functioning, further neurological assessment was recommended. The ultimate finding was that this student had a brain tumor.

In fact, many researchers highlight the importance of a neuropsychological evaluation, or at the minimum, assessing neuropsychological components. Feifer and Della Toffalo (2007) comment specifically on the aforementioned criticisms, indicating, “Therefore, proponents of RTI tend to dismiss cognitive neuropsychological assessment as being nothing more than an extension of, or a thinly-disguised version of, the discrepancy model and therefore believe it has no place in the process of identifying learning disabilities” (p. 133). Feifer and Della Toffalo also go on to defend the importance of these evaluations despite criticism, indicating, ”Research in the cognitive neuropsychology of reading has shown us that the time has also come to stop questioning whether neuropsychological processes (including phonological processing, language development, working memory, and rapid naming skills) are related to reading skill acquisition” (p. 134).

Miller (2007) discusses a conceptual model for school neuropsychological assessment. Miller outlines that one must start with the assessment of the most basic of skills, which are attention, sensory, and motor functions. From there, Miller endorses the assessment of visual-spatial skills and language processes. Memory and language skills are highlighted as important to measure. Finally, Miller endorses the assessment of both speed processes and executive functions. Clearly the model specified by Miller is quite different from the perspective of many who espouse the RTI-only approach (Feifer & Della Toffalo, 2007). Such a contrast of how to engage in assessment can leave school psychologists without direction for best practice in assessment.

Other researchers have also found links between cognitive abilities and academic outcomes. One theory that has presented with a solid research base is the Cattell-Horn-Carroll (CHC) theory of human cognitive abilities. It is the basis of a number of contemporary cognitive assessment instruments including the Woodcock-Johnson Tests of Cognitive Abilities-3rd Edition (Woodcock, McGrew, & Mather, 2001), the Kaufman Assessment Battery for Children-2nd Edition (Kaufman & Kaufman, 2004), the Stanford-Binet Intelligence Scales-5th Edition (Roid, 2003), and the Differential Abilities Scales-2nd Edition (Elliot, 2007). Hale and Fiorello (2004) specifically comment on CHC theory, commenting, “Taken together, the thorough analyses embodied in a cross-battery approach, and the extensive database used for linking CHC cognitive abilities to academic achievement domains, provide irrefutable evidence that our understanding of cognitive functioning has grown immensely and that practitioners should incorporate this knowledge into their daily assessment practices” (p. 14). A number of works have related CHC abilities to academic outcomes (Flanagan, Ortiz, Alfonso, & Mascolo, 2006; Flanagan, Ortiz, & Alfonso, 2007) and intervention (Mather & Jaffe, 2002; Mather & Wendling, 2005).

The Relationship of Curriculum Based Measurement to Reading Ability

CBM, although having much of the groundwork laid in the 1970s, has had extensive research completed in the 1980s, 1990s, and 2000s. A number of studies and books have been devoted to researching and teaching about CBM. Largely explored by Stanley Deno in the 1970s, CBM emerged from Deno's attempts to provide his teachers with measures that could be collected regularly, graphed, and evaluated. This has since evolved into a paradigm of moving away from nationally normed tests to one where assessments are tailored to measure the magnitude of discrepancy between a student from his or her local cohort and to measure sensitive change in progress (Shinn & Bamonto, 1998).

One frequently utilized measure of CBM that has been used extensively is an instrument known as the Dynamic Indicators for Basic Literacy Skills (DIBELS). This instrument, developed out of the University of Oregon, purports to measure skills related to the readiness of reading (Good, Kaminski, Moats, Laimon, Smith, & Dill, 2002) One study by Elliott, Lee, and Tollefson (2001) was implemented to view the reliability and validity of the DIBELS. The study found that 73% of the variance in scores on the Woodcock-Johnson Psychoeducational Battery-Revised was accounted for the DIBELS-M.

DIBELS has been extensively researched. A study by Rouse and Fantuzzo (2006) also used the DIBELS for the purpose of validity verification in an urban school district among kindergarten children. Results revealed moderate to strong correlations relating various DIBELS measures to reading. Using the Terra Nova Reading Test, coefficients were .48 for letter naming fluency, .5 for nonsense word fluency, and .59 for phoneme segmentation fluency. All correlations were significant at the $p<.0001$ level.

Although DIBELS is a published and frequently utilized tool for CBM in the research and in use of the school systems, there are other methods of using CBM. A study by Hosp and Fuchs (2005) sought to view how CBM techniques relate to standardized measures of reading and how those measures change with age. Specifically, they used a predictive discriminant functions analysis to determine to what extent a CBM probe would predict mastery vs. nonmastery of the WRMT-R. Correlations between CBM and the subtests and total clusters of the WRMT-R were all statistically significant at the $p<.01$ level in every grade, with r values ranging from .71 to .91. The authors also viewed to determine how well CBM predicted the various scores across grades. It was noted that CBM seemed to predict decoding best at grades 2 and 3 (hypothesized due to the lower floor at grade 1 for the WRMT and that students are less likely to decode words at grade 4 (instead reading them as whole words.)) Comprehension was not noted to be sensitive across grade levels. Overall, this study again illustrates the strong relationship of CBM on normative outcome-based measures.

A study by Shinn, Knutson, Collins, Good, and Tilly (1992) also related CBM to reading skills on the Woodcock tests (using word identification and word attack for “decoding” and reading vocabulary and passage comprehension for “comprehension”). Associations between oral reading fluency showed correlations of about .89-.90 for decoding and .74-.75 for comprehension. Associations for reading nonsense words were .56 for decoding and .57 for comprehension. No significance values were reported. Overall, CBM showed moderate to strong associations with outcomes measures on the Woodcock Reading Mastery Test.

Another study completed by Neddenriep, Hale, Skinner, Hawkins, and Winn (2007) sought to relate reading comprehension rate as a predictor of reading comprehension. One measure utilized by the authors is a CBM technique where the number of words read correctly per minute were recorded. In the fourth grade, the correlation between the CBM measure and the broad ability score of the WJ-III was .837. It was .870 for fifth graders and .755 for tenth graders. All three were significant at the .01 level.

Another CBM technique purported to relate to reading comprehension is called “Maze”. In a maze assessment, a text eliminates the seventh (or other arbitrarily set number) word from a reading text, with three other words (only one of which fits) are provided below the bank. A study by Ardoin et al. (2004) sought to look at incremental validity when administering a Maze probe beyond regular CBM-R (Reading Curriculum-Based Measurement) probes in universal screening. It was found that although maze correlated with passage comprehension, it was not a significant predictor in a multiple regression after R-CBM probes were entered.

Another study by Fuchs, Fuchs, and Compton (2004) also supported the use of CBM measures on outcome variables. This study compared the CBM techniques of word identification fluency (how many words one can read in a minute) and nonsense word fluency (how many sounds from nonsense words can be correctly read in a minute) with various outcomes, including the Word Attack subtest of the WRMT-R, the Word Identification Subtest of the WRMT-R, and the Comprehensive Reading Assessment Battery. It was found that word identification fluency consistently showed stronger predictive validity over nonsense word fluency on all of the outcomes.

A study by Hills (2005) sought to look at the relationship between both Reading Recovery and R-CBM to various measures on the WJ-III. Hills found significant relationships between R-CBM to letter-word identification (r = .83) and passage comprehension (r = .79). These were significant at the .01 level. This study also looked at R-CBM as it related to the basic reading skills cluster on the WJ-III.

Correlations ranged from .78-.89 showing strong associations again all significant at the .01 level.

There can be debate as to whether one who can quickly read might simply be a “word caller” and not necessarily read with comprehension. A study by Hamilton (2001) looked at both reading fluency (R-CBM) and the maze technique as it related to the passage comprehension subtest on the WRMT-R. Correlations between the WRMT-R and R-CBM were at .5 for the total sample (.43 for word callers and .22 for similarly fluent peers) and between the WRMT-R and maze were at .30 (.22 for word callers and .38 for similarly fluent peers). Overall, generally moderate correlations were noted between these CBM measures and the outcome reading measure. Significance levels were not reported in this study.

One of the most comprehensive studies that related CBM to reading was a literature synthesis performed by Wayman, Wallace, Wiley, Ticha, and Espin (2007). In their study, they utilized three CBM methods: Reading aloud, Maze, and Word Identification. They chose not to include measures from DIBELS in their study. Correlations in their studies with all three methods ranged from the .3s to the .8s.

It can be helpful to look at some of the studies cited specifically in Wayman et al. (2007), particularly those that used the Woodcock tests as dependent measures. One of the techniques used was “reading aloud”, which is the number of words read correctly. The aforementioned study by Hosp and Fuchs (2005) was included, which again revealed correlation coefficients ranging from .71 (word attack) to .91 (word identification) on the Woodcock Reading Mastery Test. Another study by Fuchs and Deno (1992) showed associations of .89-.93 relating words read correctly to the passage comprehension subtest on the Woodcock Reading Mastery Test.

Another technique cited in the Wayman et al. (2007) literature synthesis was the maze technique (providing a passage with words missing and the examinee must select the correct word from a choice of three presented.) Only one study by Ardoin et al. (2004) was included in the synthesis. Ardoin et al. (2004) looked at a variety of variables and how they were intercorrelated. When the number of words read correctly was correlated with subtests of the WJ-III, the relationships were .7 for broad reading, .74 for reading fluency, .42 for passage comprehension, and .62 for letter-word identification. All of the aforementioned relationships were statistically significant at the $p<.01$ level.

Clearly, the use of CBM, as noted in the aforementioned studies, presents with a strong capacity to predict performance on various normative outcome measures. Indeed, it can be seen that a number of studies support the notion that solid performance on various CBM probes in the area of reading can provide quick and effective ways of flagging how students are likely to perform on various outcome measures in reading.

Use of Cognitive and Neuropsychological Techniques

Although the use of CBM techniques have been shown to be repeatedly significantly correlated with reading outcome-based measures, it is important to recall that there are some who are advocating that a cognitive processing perspective has not shown to be a necessary nor a best practice method for identifying learning disabilities. Therefore, it is important to review some of the problem solving research that shows the relationship of cognitive or neuropsychological measures as they predict academic performance. This section will review the relationship of short-term memory and processing speed as they relate to reading skills.

The Relationship of Short-Term Memory to Reading

The construct of short-term memory has been a heavily studied skill in the literature. Perhaps one of the most studied and researched frameworks is the one that was conceptualized by Baddeley in 1974 and has been evolving (Dehn, 2008) According to Baddeley, there are three systems which govern the working memory system: the central executive, the visuo-spatial sketchpad, and the phonological loop. The phonological loop retains information heard in auditory memory for a brief period of time, while the visuo-spatial sketchpad holds visual information in working memory. These processes are mediated by the central executive through analysis and rehearsal. The central executive also mediates what information goes into long term storage (Floyd, 2005). Although Baddeley's model is one model of short-term memory, there are also other frameworks

The relationship of short-term memory to reading has been long-standing in the research literature. One framework which well illustrates this is the Cattell-Horn-Carroll (CHC) theory of cognitive development. The underlying principle of CHC theory is that there are roughly seven cognitive abilities (outside of those traditionally measured by achievement tests), which include: crystallized intelligence (*Gc),* fluid reasoning (*Gf),* short-term memory (*Gsm),* processing speed (*Gs*), auditory processing (*Ga*), long-term storage and retrieval (*Glr*), and visual-spatial processing (*Gv*). The relationship of short-term memory to reading has been well established psychometrically (Flanagan & Mascolo, 2005; Flanagan, Ortiz, Alfonso, & Mascolo, 2006). Furthermore, working memory has been associated with Baddely's "phonological loop" which has been noted as important in reading in neuropsychological literature (Miller, 2007; Semrud-Clikeman, 2005).

One study by Evans, Floyd, McGrew, and Leforgee (2001) sought to understand the relationship of short-term memory to reading using the standardization sample of the WJ-III. According to their study, "The Short-term Memory (*Gsm*) cluster displayed consistent moderate relations with Basic Reading Skills" (p. 252). Multiple regression coefficients ranged from .1 to almost .3 depending on the age of the student. This relationship, however, was not noted with reading comprehension. Nevertheless, the importance of this finding is salient given that the study revealed most of the CHC factors were only prevalent during a certain developmental period. For example, auditory processing was only salient during the earlier years but short-term memory remained important in having a moderate relationship to basic reading skills. Significance values were not reported.

Another study by Osmon, Braun, and Plambeck (2005) showed results similar to Evans et al. (2001). Specifically, letter word identification and word attack were moderately correlated with the Gsm factor on the Woodcock-Johnson Revised, with correlations in the .4s (.44 and .45 for letter word identification and word attack respectively.) Significance levels were not reported.

Although other studies have not highlighted the importance of short-term memory to reading within the CHC framework, the importance of this skill is still well-noted in the research literature as it relates to reading. One study by Swanson and Jerman (2006) highlighted the importance of working memory as more important related to reading than overall short-term memory. Specifically, using Baddeley's framework, controlled attention related to working memory was much more important than the overall phonological loop.

There has been speculation that difficulties with short-term memory and reading may have a heritability factor. A study by Raskind, Hsu, Berninger, Thomson, and Wijsman (2000) sought to link familial patterns related to dyslexia. Although there is an abundance of research related to phonemic awareness and reading (Gresham, Restori, & Cook, 2008), it is interesting to note that the authors of this study state, “These results suggest that the genetic constraint is at the level of phonological memory rather than phoneme awareness, as an aggregation pattern consistent with a genetic basis was not found in either of two measures of phoneme deletion” (p. 392). In other words, although the reading disorders were noted in the family history, it was actually short-term memory which provided a dual linkage, as opposed to phonemic awareness.

Another study by Berninger et al. (2006) viewed a variety of factors believed to be related to reading and writing outcomes in both children and adults. Specifically, the predictor skills were phonological word-form storage, time sensitive phonological loop, and executive functions involving phonology. A variety of measures were used to tap the latent variables of phonological, orthographic, and morphological word form. There were a variety of dependent variables, although the only ones of interest are the results of the WRMT-R Word Identification subtest, the WRMT-R Word attack Subtest, the GORT3 Oral Reading Accuracy, the GORT3 Oral Reading Rate, and Reading

Comprehension from both the WJ-R and the GORT3. For Phonological Word Form (with the CTOPP Elision, Phoneme Reversal, and Nonword Repetition Subtests), unique paths were noted for the Word Attack subtest at the $p<.01$ level and Word Identification subtest at the $p<.05$ level. For Orthographic Word Form, three subtests from the Process Assessment of the Learner (or PAL) were used including the Receptive Coding, Expressive Coding, and Word Choice subtests. Unique paths were found for the GORT3 Oral Reading Accuracy and Rate subtests at the $p<.01$ level, and for the WRMT-R Word Identification and subtest at the $p<.001$ level. Finally, for Morphological Word Form, which was comprised of the Carlisle Decomposition task and the University of Washington Morphological Signals Task showed a unique path for the Reading Comprehension outcome measure (for WJR and GORT3) only at the $p<.05$ level. The authors then looked at a Second-Order Word Form which showed unique paths for the GORT-3 Accuracy, Rate, and for Reading Comprehension all at the $p<.001$ level. Although the latent variable of “Phonological Loop” did not yield significant results, the variable noted as Executive Support for Language (consisting of a rapid automatic switching task and the Color Word Inhibition subtest of the Delis-Kaplan Executive Function System) showed a unique path for GORT-3 rate at the $p<.01$ level. Although there are some questions to this study (for example, why did the authors elect to use the WRMT-R for Word Identification but the WJ-R for Passage Comprehension when both subtests are on both measures), the complexity and unique variability evidenced by unique cognitive predictors is noteworthy. Specifically, the differential characteristics predicting the different outcomes (that is, word identification, vs. word attack, vs. reading fluency, vs. reading comprehension) are not only noteworthy, but also give insight into the complexity of reading. The use of a short-term memory subtests to relate to the phonological word form difficulties related to reading (CTOPP nonword repetition) is also relevant.

Another study by Joseph, McCachran, and Naglieri (2003) also related how certain normative cognitive tests relate to the concept of short-term memory. According to the authors, the successive scale of the Cognitive Assessment System was “the best predictor of phonological memory” (pp. 311-312). Furthermore, the results indicated that, “Generally, the cognitive characteristics (i.e. low successive processors) among the sample of referred primary-grade children in the current study seemed to be consistent with characteristics of poor readers” (p. 311). Although the results highlighted other cognitive variables (such as phonemic awareness) as stronger correlates of reading, the r values of both phonological memory and the successive processing subtests were all within the .4 range, showing some correlation with both word identification and word attack. The correlation was not significant, although it was noted that they set their alpha level at $p<.001$ after the Bonferonni Error Correct Procedure.

One study by Naglieri and Reardon (1993) also sought to examine the importance of the skills measured by the CAS when differentiating between those who were disabled and those who were not. The variable with the highest predictor of reading was the successive factor for the reading disabled, which again, taps short-term memory (r = .5 for basic reading skills on the Wide Range Achievement Test and .52 for reading comprehension on the WJ-R), which were both significant at the .01 level. Interestingly, only the simultaneous factor had a significant correlation for the nondisabled and that was only for reading comprehension (no variables related to reading among the non disabled). Although these are only correlations and not treatment results (so no ATIs could be determined), it is interesting to note that the profiles are significantly different between the disabled and nondisabled population.

The importance of the successive factor on the CAS has also been identified in another study. A study by Naglieri and Rojahn identified a mild to moderate correlation on the whole sample (n = 1559) related to successive processing and basic reading skills (r = .33) and reading comprehension (r = .31). However, a closer look at the breakdown in ages revealed the highest correlations from students aged 8-10 (r = .41 for basic reading and r = .5 for reading comprehension) and ages 11-13 (r = .52 for basic reading and .5 for reading comprehension) than aged 5-7 (r = .29 for basic reading and r = .22 for reading comprehension) and ages 14-17 (r = .39 for basic reading and .37 for reading comprehension). Significance levels were not reported in the study. As stated earlier, the importance of short-term memory may hold greater relevance at some ages more than others. There have been other studies that have compared working memory and reading outcomes. A study by Swanson and Howell (2001) investigated the role of both verbal and visual working memory on reading outcomesThe WJ-R was used as a criterion measure and varied measures of short-term memory were used as predictors. Significant correlations were found relating short-term memory to reading recognition (r range = .45-.58, p<.001) and slightly more modest (although still significant) correlations were found relating these predictors to reading comprehension (.21-.32 (all correlations were significant at the p<.05 level except for verbal working memory where p<.01)).

A study by McCallum et al. (2006) also sought to view the role of working memory and other cognitive processes related to reading ability. Using the Test of Dyslexia subtests, it was noted that auditory letter memory was correlated with reading comprehension (.28), reading fluency (.36), and decoding (.50). Visual letter memory was correlated highly with reading comprehension (.44), reading fluency (.46) and decoding (.43). All correlations were significant at the .01 level. Afterward, a multiple regression was conducted with memory measures entered last. When memory was entered in with other processing variables (orthography, phonology, and rapid naming), strong prediction was shown with a total of 32.6% of the variance accounted for in comprehension and 46.4% of the variance accounted for in reading decoding. Again the influence of cognitive processing seems readily manifest when correlating with reading outcomes.

A study by John and Rattan (1991) investigated the importance of short-term memory for both learning disabled students as well as educable mentally retarded students. John and Rattan discovered that while there was variability of the prediction of short-term memory for reading success, that a memory for sentences task (repeating sentences as they were said) was the best predictor of reading achievement for learning disabled students.

There are some researchers who maintain that it is more important to look at full scale scores when compared to achievement, rather than looking at component skills (Watkins, Glutting, & Youngstrom, 2005; Frazier & Youngstrom, 2007), others have specified the importance of looking at the skills which impact achievement. Research by Hale, Fiorello, Kavanagh, Hoeppner, and Gaither (2001) identified how certain skills on the WISC-III related to academic achievement. Related to short-term memory, the authors looked at the freedom from distractibility factor, which has subtests measuring short-term memory as well as quantitative reasoning. The relationship of the freedom from distractibility factor related to both reading decoding (r = .48) and reading comprehension (r = .39). The short-term memory factor on its own related to reading decoding (r = .42) and reading comprehension (r = .3). Significance values were not reported. The addition of the arithmetic subtest seemed to result in a stronger relationship to reading, possibly because of its higher reliability (generally clusters are more reliable than single subtests alone (Watkins et al., 2005)), or also because there is an element of short-term memory also related to the arithmetic subtest. Nevertheless, it is interesting to note that the freedom from distractibility factor had the highest relationship to reading decoding within the entire study.

A review of the aforementioned research generally has yielded consistent results. Specifically, that short-term memory generally has yielded moderate relationships to reading decoding and reading comprehension (with r values ranging from .3-.5, suggesting 9-25% of the variance accounted for by this factor).

The Relationship of Processing Speed to Reading

Processing speed is an area that is tapped by many tests and has been noted to be a construct of value as it is present in both cognitive and neuropsychological batteries. The definitions of processing speed vary. According to McGrew and Flanagan (1998), "Processing Speed is the ability to fluently perform cognitive tasks automatically, especially when under pressure to maintain focused attention and concentration" (p. 24).

As noted, processing speed has long been held as a variable of interest, particularly within the fields of cognitive and academic assessment. Perhaps it is ironic that a processing speed subtest, Coding, that has one of the lowest loadings to *g* on the WISC-IV (Sattler & Dumont, 2004) has been included again and again in test revisions. Zhu and Weiss (2005) cite a number of studies that highlight Coding as a sensitive subtest to those who have sustained brain injury. According to Reitan and Wolfson (1992), the adult version of coding (digit symbol) "has been consistently identified as the most sensitive of the Wechsler Scale subtests to cerebral impairment, regardless of whether the damage involves the brain diffusely or principally the left or right cerebral hemisphere" (p. 122). Other measures of processing speed are also no more than a fair *g* loading (Sattler & Dumont, 2004). Despite the tendency for processing speed to be no more than a fair predictor of 'g' yet sensitive to differentiating clinical populations makes it a variable of significant interest.

Processing speed is important given its relationship to certain other variables needed for academic success (e.g. Mather & Wendling,

2005) but concerns are present about the potential for its underuse and varied frameworks for defining this construct. As previously stated, some believe that only *g* should be the construct of interest when assessing for learning disabilities (Watkins, Glutting, & Youngstrom, 2005) or that test authors are naming too many factors rather than focusing on a single unitary construct (Frazier & Youngstrom, 2007). Others indicate that factors such as processing speed or short-term memory are the actual learning disabilities, which artificially deflate the cognitive score, thereby preventing a discrepancy (Dumont & Willis, 2009).

Processing speed can be a difficult concept to define. There seems to be agreement that most tests which measure speed of motor processing tap processing speed (Wechsler, 2002; McGrew & Flanagan, 1997; Woodcock, McGrew, & Mather, 2001). Another skill that has been deemed important in reading is a concept known as *naming speed or rapid automatic naming (RAN).* RAN is how quickly one can verbally respond to information. There is debate as to whether this is subsumed under the term “processing speed” as some tests that tap both motor speed and naming speed do not look at naming speed as a subset of processing speed (Woodcock, McGrew, & Mather, 2001) while others do (Elliot, 2007). Referring back to the aforementioned definition of processing speed, it seems that naming ability certainly fits under the category.

Comparing RAN skills to reading has a long history. It is one prong of what Wolf and Bowers (1999) call the *double-deficit hypothesis* to reading problems. This was based on a numerous studies that identified both phonological processing and rapid naming deficits as germane to students with reading disabilities. The problems with rapid naming could be resultant of problems with the visual system (Wolf & Bowers, 1999) or could be resultant from inefficiency in retrieving information from long-term memory (McGrew & Flanagan, 1998). Regardless, the importance of comparing processing speed to reading seems to be well substantiated by the problem solving literature.

As indicated, there are a number of studies which relate processing speed to reading. One validity study conducted by Havey, Story, and Buker (2002) sought to determine the relationship between subtests of the CTOPP (Wagner, Torgesen, & Rashotte, 1999) and reading. The rapid naming cluster correlated with the letter-word identification of the WJ-III at .49, showing a moderate correlation between these variables. This correlation was significant at the .01 level.

A similar study by Georgiou, Parrila, Kirby, and Stephenson (2008) sought to look at various RAN tasks as they correlate to word reading ability (particularly the naming of colors, digits, and letters). The range of correlations between RAN time (the longer the time, the worse the performance) ranged from -.09 to -.47, showing weak to moderate correlations between RAN and letter-word identification. Multiple analyses were conducted. Correlations at the -.27 to -.34 tended to be significant at the .05 level and those that exceeded -.36 tended to be significant at the .01 level.

A study by Mariko-Doi (1996) also sought to determine the relationship of RAN to reading ability. In this study, the participant was required to rapidly name digits, numbers, or objects. The results were correlated with both word identification and word attack measures. Again, with RAN time being the first variable, the correlations for the various RAN tasks ranged from = -.17 to -.70 (and when the object task was removed, the range was -.56--.70 showing moderate to strong negative correlations between naming time and word identification ability.) Again, multiple comparisons were made. Mariko-Doi noted that correlations from .22-.28 were significant at the .05 level, from .29-35 at the .01 level, and at or above .3 significant at the .001 level.

One study by Raskind, Hsu, Berninger, Thomson, and Wijsman (2000) sought to determine the nature of genetic influence on reading problems with a variety of predictor factors, including verbal IQ, short-term memory, and naming ability. The influence of RAN on word identification as well as passage comprehension correlated at about .4 for both letters and numbers, showing, again, a moderate correlation.

It is important to note that significance levels were not reported in this study.

As previously indicated, processing speed includes more than just RAN tasks. Speeded paper-pencil tasks have been a hallmark of processing speed tests. One study by Urso (2008) sought to look at a number of cognitive skills as they related to reading ability. When processing speed was looked at individually, there was a .4 correlation (significant at the .01 level) between processing speed and basic reading skills (which includes reading both real and nonsense words) as well as .5 (significant at the .01 level)for the letter-word identification subtest in isolation. Again, moderate correlations were noted between processing speed and reading ability.

Another study also reached somewhat similar conclusions. A study by Miller (2001) analyzed the impact of cognitive variables on measures of reading for middle school students. Ironically, although processing speed was not a significant predictor of reading fluency, it was a significant predictor (along with short term memory and crystallized intelligence) of word identification skill. Processing speed also, however, was not significantly predictive of reading comprehension.

Although easy to overlook, reviewing the results of norming samples for standardization measures is also helpful as they usually are used to make generalized statements about the construct being measured. A review of the Technical Manual for the WJ-III (McGrew & Woodcock, 2001) provided information on processing speed as it relates to reading. When reviewing the intercorrelation tables, processing speed correlated at .54 for broad reading skills at ages 6-8 (.5 for basic reading and .48 for reading comprehension, at .53 for broad reading skills at ages 9-13 (.37 for basic reading skills and .38 for reading comprehension), and .57 for broad reading for students aged 14-19 (.4 for basic reading skills and .37 for reading comprehension skills.) One important finding from these results is the role of processing speed is clearly more important at earlier ages related to the prediction of reading. These were statistics reporting the findings of the standardization sample and significance levels were not reported.

A study by Bowers, Steffy, and Swanson (1986) also related the importance of processing speed to reading. Bowers et al. sought to determine the relationship of naming speed and short-term memory to reading. Digit naming speed and color naming speed were used as measures of naming speed. Digit naming speed correlated at .57 ($p<.001$) for letter-word identification and .44 ($p<.01$) for passage comprehension (color naming speed was only significant for word attack). A multiple regression analysis revealed that the addition of digit naming speed to the control variables accounted for statistically significant contributions of variance explained for the reading cluster ($p<.001$), word attack ($p<.001$), letter-word identification ($p<.01$) and passage comprehension ($p<.05$).

The relationship between naming speed and reading also was similar in a study by Bell, McCallum, and Cox (2003). Bell et al. sought also to relate the relationship of various cognitive processing factors to reading. Rapid naming was correlated to letter-word naming at .57 and at .44 (both significant at the .01 level) for reading comprehension, again revealing moderate correlations between these variables.

Overall, review of the literature of processing speed as it relates to reading skills has been relatively consistent. Generally, moderate correlations between measures of processing speed and word reading skills as well as low-moderate correlations noted between processing speed and reading comprehension.

The Use of Meta-Analysis

There are many different methods to data analysis when attempting to answer a question asked in the social sciences. Most statistical analysis techniques will reveal a variety of relationships such as: a metric that reflects the strength of association between or among variables, reveal the magnitude of mean differences, identify the power of prediction one variable has on another, or identify how well an a priori model fits among observed or latent variables. However, these types of analyses usually involve very restricted data. The sample may be constricted to a geographic location, be constrained to certain environmental variables (such as when the research was conducted), or be influenced by specific limitations that may have impacted a particular study. In order to establish more confidence about a research question, it can be helpful to analyze multiple studies at once. This can be accomplished through meta-analysis.

Meta-analysis was first coined after Gene Glass first conducted a synthesis of studies to dispute the claims by Hans Eyseneck that psychotherapy did not have beneficial outcomes on patients (Lipsey & Wilson, 2001). This resulted in a heightened interest in research synthesis. Now, meta-analysis is a frequently used statistical technique that looks at the synthesis of studies to determine the various effect sizes that a specific treatment may have, or will determine the strength of association between variables.

Kavale and Glass (1981) reviewed how meta-analysis is superior to other methods of research integration. One method is the narrative review, where researchers would simply research past studies and create a verbal report. Unfortunately, there was little use of psychometrics and the subjectivity of which studies would be included and discarded was a significant problem. Box-score analysis, or the “voting method” was another attempt at research integration. This methodology simply allowed the researcher to tally whether a study had significant results or if they didn’t. According to Kavale and Glass, this did not take varying sample sizes into account. Another issue is publication bias (studies not showing significance are often not published.) The logical answer was to employ a meta-analysis where the goals are: "(a) to eliminate bias in study selection-studies should not be excluded on arbitrary and *a priori* grounds; (b) to make use of all information-study findings should be transformed to commensurable expressions of magnitude of experimental effect or correlational relationship; and (c) to detect statistical interactions-study features that might mediate findings should be defined, measured, and their covariation with findings studied" (Kavale & Glass, 1981, p. 532.)

The goals of meta-analysis are relatively straightforward. Specifically, meta-analysis seeks to determine if the magnitude of treatment change or strength of association is consistent across studies. Doing so creates what is known as an *effect size.* According to Lipsey and Wilson (2001), "An effect size is a statistic that encodes the critical quantitative information from each relevant study finding. Different types of study findings generally require different effect size statistics" (p. 3). Lipsey and Wilson also indicate that the best types of effect sizes identify both magnitude and direction of relationships, not simply statistical significance.

Since its genesis in the mid 1970s, meta-analysis has enjoyed prominent use as a defensible data-collection technique. Its utility within the social science as well as education has been well-established. One study by Lloyd, Forness, and Kavale (1998) cited the use of meta-analysis to help make informed decisions on the utility of interventions for special education; they highlighted how the interested researcher can use effect sizes to determine the efficacy of an intervention.

Perhaps one of the most prominent meta-analyses was completed by Swanson (1999). In his study, Swanson reviewed and synthesized data from 272 studies to determine the effect sizes of various interventions for students with learning disabilities. A few important highlights from his study include Swanson's discovery that certain aptitude variables, such as overall cognitive ability and severity of reading problems were important in predicting treatment outcomes. He also found that both whole word strategies as well as phonics both make significant contributions to treatment outcomes and one does not supersede the other. The utility of meta-analysis is clearly manifest; although any study might say something about a sample of subjects, a meta-analysis combines those results in order to unearth trends for those studies that generally measure the same constructs.

Lipsey and Wilson (2001) review how to perform a meta-analysis. The first thing that needs to be done is the researcher must identify what type of analysis will be done (odds-ratio, mean difference, correlation, etc.) Next, the researcher must identify what types of characteristics must be present in order to be eligible to be in the study. This includes the distinguishing features of a qualifying study, research respondents, key variables, research designs, cultural and linguistic range, time frame, and publication type. Next, the researcher must identify the methodological quality of the studies to be included. Finally, the studies are selected from the pool of research that meets the inclusive criteria.

The techniques of meta-analysis vary. Best practice indicates that a coding form is often used to help select studies in order to reduce selection-bias (that is, favoring the selection of studies that may favor the researcher’s hypothesis). The form identifies the characteristics that may typify any study, which helps the researcher select studies for inclusion (Lipsey & Wilson, 2001; Swanson, 1999). Nevertheless, a defensible meta-analysis can be done without a specific coding form if the criteria are narrow enough that selection bias does not occur (for example, see Vanvoorhis, 2003).

Summary

The preceding discussion overviewed the problem solving research of CBM and cognitive processing measures as they predict reading. It also reviewed the techniques of meta-analysis. Specifically, there is ample research exploring both the CBM and cognitive/neuropsychological processing perspectives in terms of relating to reading decoding, fluency, and comprehension outcomes. Furthermore, meta-analysis presents as a sound research technique in which to synthesize studies to determine overall trends with the variable(s) of interest.

Chapter III

METHODS

Overview

This chapter will describe the procedures for the execution of this study. Initially, the research design will be discussed followed by a description of the population and sample. Next, the measurement techniques will be reviewed, along with the identification of latent and observed variables. Finally, the procedures to implementing the study will be presented.

Design

This study is a meta-analysis of the past research relating various measurement techniques to various outcome measures. Specifically, studies comparing curriculum-based measurement techniques relating to outcomes in reading, as well as studies comparing short-term memory and processing speed relating to outcomes in reading were chosen. The correlations were analyzed and the effect sizes (strengths of association) of the correlational relationships were also analyzed. Specifically, the effect sizes compared constructs relating CBM to both basic reading and reading comprehension. Effect sizes between both short-term memory and processing speed were also compared to basic reading skills and reading comprehension. Finally, both the variables of short-term memory and processing speed were combined using a moderator variable called “cognitive” while all curriculum-based measurement studies were grouped using a variable called “CBM”. The effect sizes (correlations) between the cognitive and CBM variables were measured for both basic reading skills and reading comprehension. Because it was assumed that many of the selected studies were going to be very different, a random effects model was chosen ad hoc. According to Lipsey and Wilson (2001), “In a homogenous distribution, the dispersion of the effect sizes around their mean is no greater than that expected from sampling error alone (the sampling error associated with the subject samples upon which the individual effect sizes are based). In other words, in a homogeneous distribution an individual effect size differs for the population mean only by sampling error” (p. 115). Also, according to Lipsey and Wilson, the random effects model takes into account variance that occurs outside of sampling error. A logical path diagram of this study is shown in Figure 2. It is important to note that due to the very large number of predictor variables present, the path diagram represents only a very abbreviated representation of the whole study, with only one observed measure for each latent variable reported simply to give the reader an idea of the design of the study.

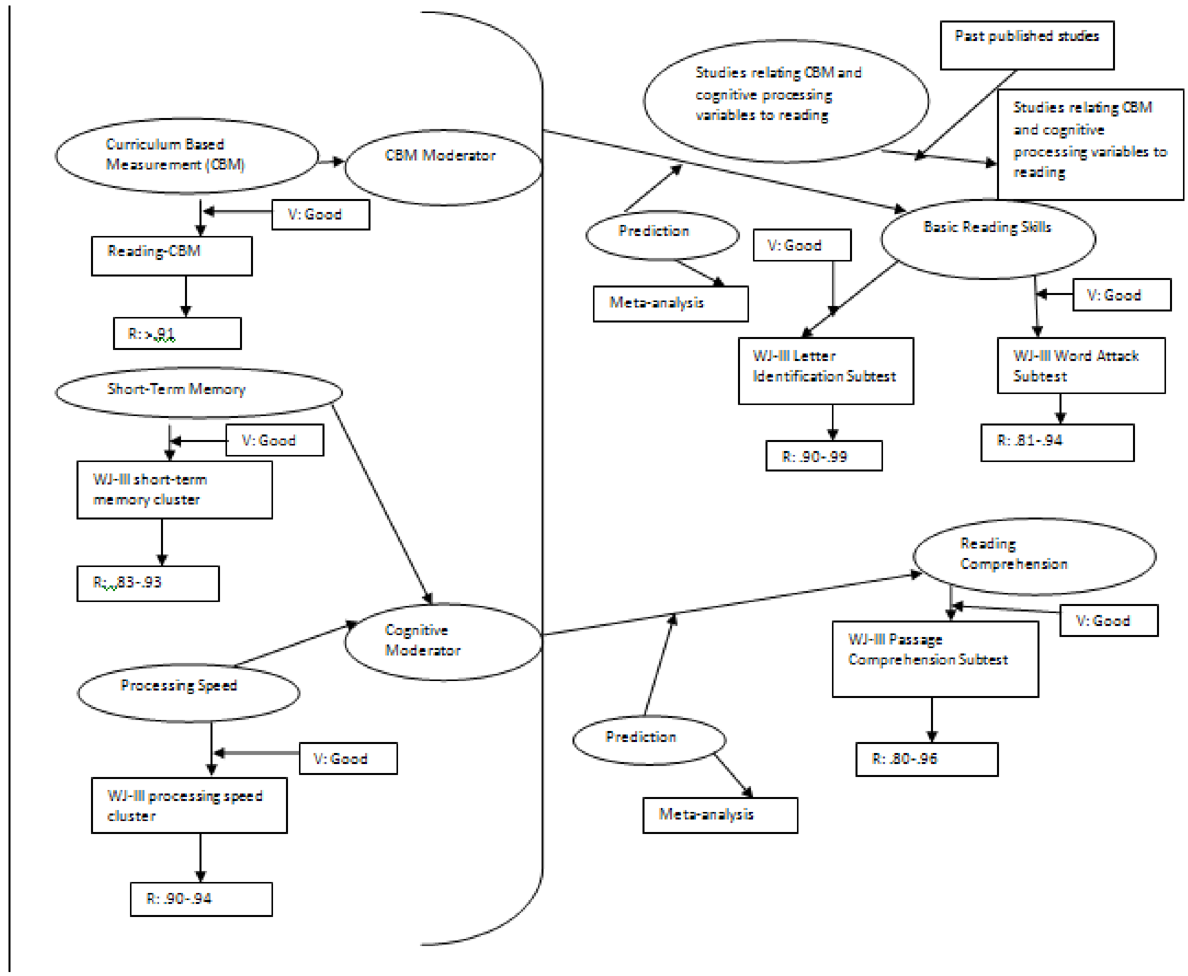

Figure 2. Logical path diagram identifying the design of the research.

Population

The population represented in this study should be representative of all people to whom CBM as well as short-term memory and processing speed correlates to outcomes in basic reading skills and reading comprehension. Because the processes that are related to reading differ with regard to age (Evans et al., 2001), the allowable age range of participants for any given study was to be between the ages of 4 and 14. Although there has been research to show that the sex of an individual has been an influential factor with regard to reading, particularly reading disabilities (Liederman, Kantrowitz, & Flannery, 2005), a preliminary review of the literature revealed that most studies did not separate sex when comparing reading skills to these processes. Therefore, sex was not a consideration when selecting studies.

Sample

The sample, specifically, consists of the studies chosen for analysis. No actual human participants were researched in this study, because a meta-analysis is a research technique used to look at the magnitude of comparable research in past studies. The sample consisted of 13 studies and 55 measured associations when comparing CBM to basic reading skills. When CBM and reading comprehension were compared, 11 studies containing a total of 23 measured associations were harvested. The comparison of short-term memory to basic reading skills resulted in 14 studies and 49 measured associations. Eight studies with a total of 35 measured associations were found when comparing short-term memory to reading comprehension. The processing speed sample resulted in 17 studies (123 measured associations) when compared to basic reading skills and 7 studies (38 measured associations) when compared to reading comprehension. No specific criteria is noted on the number of studies needed to run a meta-analysis. The lowest number of studies that were found in a meta-analysis was eight (VanVoorhis, 2003) while others have as many as over 250 (e.g. Swanson, 1990). Although the comparison of processing speed to reading comprehension is the smallest with only seven studies, it is important to note that 38 associations were compared, which brings the sample size in line with other published research.

Assignment

For the purposes of this study, assignment shall mean the techniques used to choose studies for analysis. Specifically, the inclusion criteria followed the characteristics as noted by Lipsey and Wilson (2001):

Distinguishing Features

1. The predictor variables are "Curriculum Based Measurement", "Short-Term Memory", or "Processing Speed" and the outcome variables are "Basic Reading Skills" and "Reading Comprehension". The operationalization of these constructs are described in the "measurement" section below.
2. Because this is a correlational meta-analysis, all studies required a correlation coefficient between the predictor and outcome variables of interest.
3. The outcome measures were limited only to: The Woodcock Reading Mastery Test-Revised, The Woodcock-Johnson Revised, and the Woodcock Johnson Tests of Achievement-3rd Edition. The reason for this restriction is these three tests tend to use similar methods to identify their latent variables (specifically basic reading and reading comprehension.) (Woodcock, 1987; Woodcock & Johnson, 1990; Woodcock, McGrew, & Mather, 2001). For example, all three of these tests use a cloze method (determine the missing word) as a method to identifying reading comprehension. These tests were chosen because they appeared with the greatest frequency in the literature when used as a dependent variable to assess both basic reading skills and reading comprehension. This was determined by doing a search in the ERIC, PsychINFO,

PsychARTICLES, and Psychology and Behavioral Sciences collection. At the time of this research, the term "WJ" resulted in 275 hits while the term "Woodcock reading" resulted in 285 hits. In contrast, the term WIAT (for Wechsler Individual Achievement Test) resulted in 100 hits and KTEA (for Kaufman Test of Educational Achievement) resulted in 20 hits. It is important to note that the Woodcock tests sometimes yield a "Broad Reading" cluster that comprises both basic reading skills and reading comprehension skills. Although composite scores lose specificity, they were not excluded because they tend to have higher reliabilities (Watkins, Glutting, & Youngstrom, 2005).

Research Respondents

1. As the research of interest most directly pertains to the identification of learning disabilities in the school system, the participants of selected studies, again, needed to be "school aged", indicating that they are anywhere from the ages of 4-14 of either sex. Students over the age of 14 were excluded from the study were excluded because of the differing demands of reading at the older age levels.

Key Variables

1. Again, the key predictor variables are "curriculum based measurement", "short-term memory" and "processing speed". The key outcome variables are "basic reading skills" and "reading comprehension".

Research Methods

1. Again, a study was only selected for inclusion if it included one of the aforementioned predictor variables, outcome variables, and a coefficient indicating the strength of association between those two. According to Lipsey and Wilson (2001), the nature of the selected data must be similar across studies.

Cultural and Linguistic Range

1. It was required that the selected studies were reported in English to be understood by the researcher. No other restrictions were implemented for inclusion as long as the other criteria were satisfied.

Time Frame

1. In order to ensure that the research was relatively recent but also to ensure that enough studies would be generated, a time frame of 20 years was selected for research studies. In other words, no studies before 1990 were selected for this analysis.

Publication Type

1. There were no restrictions on publication type as long as the remaining criteria for inclusion were satisfied.

Methodological Quality

1. The sample sizes of the chosen studies should be large enough to make predictions about the populations being spoken about. An ad hoc decision was made that the sample size in each study needed to exceed 10. According to Lipsey and Wilson (2001), “effect size values based on larger samples are more precise estimates of the corresponding value than those based on smaller samples” (p. 36). Lipsey and Wilson further indicate, “... an effect size value based on a sample of five subjects is not as good an estimate as one based on a sample of 500 subjects” (p. 36). The number was somewhat arbitrarily chosen and was chosen to include studies where the sample size may be smaller but may have important results, but not to be so small that generalizability becomes a significant issue.

2. The reliability of any predictor techniques (that is, tests or subtests) was equal to or greater than .70. Cohen and Swerdlik (2009) parallel reliabilities to “grades”. They indicate that reliabilities in the .90s rate a grade of A while .80s rates a grade of B. The above researchers indicate that “anywhere from .65 through .70s rates a weak “barely passing” grade” (p. 151).

A reliability of .70 was selected to ensure that enough studies fit the criteria, while not being at the lowest limit for study acceptability.

3. Any study that met the aforementioned criteria was selected for the analysis in order to eliminate selection bias. In other words, no studies were selectively chosen because if any study met the criteria, it was included.

Measurement

The outcome latent variables in this study, again, are basic reading skills and reading comprehension. The latent variables for CBM measures include Reading Curriculum Based Measurement (R-CBM) and other variables that have been associated with CBM in the literature (for example, the various indicators of the Dynamic Indicators of Basic Early Literacy Skills (DIBELS)). The latent variables for cognitive and neuropsychological processing, again, include short-term memory and processing speed. The following incorporate instruments used to measure the latent variables:

Outcome Measures

1. **Woodcock Reading Mastery Test-Revised (Woodcock, 1987):** This test is a normative based test which measures skills in basic reading and reading comprehension. Reliabilities tend to reside in the high .90 range and concurrent validity has been established for total reading.

2. **Woodcock Johnson Psychoeducational Achievement Battery-Revised (1990):** Similar to the WRMT-R, skills are measured in basic reading and reading comprehension. Reliability coefficients tend to reside in the .90s. Concurrent validity has been established through comparison with the Wechsler Individual Achievement Test. Overall validity ranges from .60-.70
3. **Woodcock Johnson Tests of Achievement-3rd Edition (Woodcock et al., 2001):** Similar to the WRMT-R and WJ-R, the WJ-III achievement tests measure basic reading skills, reading fluency, and reading comprehension. Test-retest reliability for the basic reading cluster for most 8-10 year olds was .93. The WJ-III letter word identification subtest presented with a reliability of .85. Passage comprehension was .88. Reliability for the basic reading skills cluster was noted to range from .82-.95 (depending on age) and reading comprehension (also depending on age) from .81-.95. Validity was established given correlations to other measures of achievement.

Predictor Measures for Curriculum Based Measurement

1. **Dynamic Indicators of Basic Reading Skills (DIBELS)(Good et al., 2002):** This curriculum based measurement taps nonsense word fluency, oral reading fluency, and phoneme segmentation fluency. Reliabilities tended to reside at .88 or higher. Construct validity has been established through comparison

with various reading measures, including the Woodcock tests. The average concurrent validity coefficients were .80 for Oral Reading Fluency, .58 for Nonsense Word Fluency, .44 for Phoneme Segmentation Fluency, and .55 for Initial Sound Fluency.

2. **Curriculum Based Measurement-Reading (Fuchs & Fuchs, 1992)** These are reading passages developed by Douglas and Lynn Fuchs. It has test-retest reliability of .92 or higher, depending on the grade level used. Criterion validity coefficients for instructional decision making range from .73-.81 (Ardoin et al.,2004).

3. **Maze Technique:** This technique requires that the student reads with fixed words that are randomly omitted and one of three words are offered as the correct word to logically complete the sentence. This technique has historically shown reliability of over .90. Criterion validity has been established through correlations with reading comprehension measures, yielding coefficients generally in the .8 area (Fuchs & Fuchs, 1992).

Predictor Measures for Cognitive and Neuropsychological Variables (Specifically Short-Term Memory and Processing Speed)

Note: Because over 40 types of observed measures were used for this category, they are not enumerated here. Rather, a brief definition of the types of observed variables that are subsumed under the latent variables of short-term memory and processing speed are discussed.

1. **Short Term Memory:** Measures of short term memory can include any standardized assessment (including subtest scores or factor composites) that measure the ability to hold information in short-term memory. This includes memory span (the ability to repeat information just heard, as is often typical of a “repetition of digits forward” task), as well as working memory (the ability to manipulate information in short-term memory, such as a “repetition of digits backward task”). All measures met the aforementioned inclusion criteria for the analysis with regard to sample size and having a reliability of >.70.
2. **Processing Speed:** Measures of processing speed include any standardized assessment (including subtest scores or factor composites) that measure the ability to process information in a speeded fashion. This includes both visual-motor speed tasks as well as rapid naming tasks. Examples might include the coding task on the Wechsler tests as a measure of visual-motor speed and the rapid naming tasks on the Comprehensive Test of Phonological Processing as a measure of rapid naming. All measures met the aforementioned

inclusion criteria for the analysis with regard to sample size and having a reliability of >.70.

Procedures

Studies were selected for analysis based on the aforementioned criteria. If the studies fit the criteria, they were included in the analysis to minimize the possibility of selection bias. Because this project did not use coding procedures, no study was excluded if it met the selection criteria. Studies were selected by reviewing databases including PsychInfo, PsychArticles, and ERIC. Keywords included: WJ, WJ-III, WJ-R, WRMT-R, Woodcock, basic reading, and reading comprehension for the outcome variables. They were combined with the predictor variables of interest, which included the words: short-term memory, working memory, processing speed, naming speed, rapid automatic naming, reaction time, mental chronometry, CBM, curriculum-based measurement, DIBELS, and Dynamic Indicator of Basic Early Literacy Skills. References from studies that met the criteria were also reviewed. The data was then entered into the program Comprehensive Meta-Analysis V. 2.0 (Bornstein et al., 2005) for analysis.

After the analysis was conducted between each of the predictor variables (CBM, short-term memory, and processing speed) and outcome variables (basic reading skills and reading comprehension), two more analyses were conducted. One grouped the short-term memory and processing speed analyses into a separate cluster called “cognitive” and that group was compared with the CBM variables when predicting both basic reading skills and reading comprehension. Finally, the differences in strengths of association were analyzed by using a Fisher’s r to z transformation and comparing the *z* scores. This was done by using an online calculator (Lowry, 2010). The task table for project completion is shown in Table 1.

Table 1

Meta-Analysis Timeline

#	Name	Description	Begin	End	Person
1	IRB Proposal	Provide project information to the IUP Institutional Review Board.	December 2008	IRB approved March 23, 2009.	John Garruto
2	Project Idea	Prepare and propose dissertation proposal for IUP committee	June 2009	January 2010	John Garruto
3	Select studies	After proposal defense, studies will be selected based on the pre-determined criteria.	January 2010	January 2010	John Garruto
4	Compute, analyze, interpret, and report on data	Studies will be analyzed and results and discussion will be reported.	January 2010	May 2010	John Garruto

Statistical Analyses

This section consists of a restating of each research question, along with the hypotheses, variables, statistics used, assumptions, and methods to determine appropriateness of assumptions. Because this project is a synthesis of past studies and because it consists of a wide variety of instruments that related to observed measures, latent variables will be named. All results are summarized in table 2.

Research Question 1: What is the Overall Effect Size when using CBM to Predict Basic Reading Skills?

The purpose of this question is to determine the overall effect size when analyzing past studies that compared CBM to basic reading skills. There wasn’t a hypothesis formulated as the purpose of this question was simply to review the overall effect size between these two variables. The statistical procedure used was a meta-analysis, which resulted in an overall *r* effect size. The assumptions for data included that all data analyzed conformed to the distinguishing features noted in the design of this study (including sample size, year of publication, reliabilities needed, and instruments to be

Table 2

Research Questions, Hypotheses, Variables, Statistical Analyses, and Statistical Assumptions for the Meta-Analysis

Research Questions	Hypotheses	Variables	Statistic	Assumptions	Assumption Appropriateness
1. What is the overall effect size when using CBM to predict basic reading skills?	No hypothesis formulated	CBM and basic reading skills	Meta-analysis effect size (*r*)	1. Sample Size of studies>10 2. Reliabilities of measures >.70 3. Studies published on or after 1990 4. Outcome measure is a test authored by Richard Woodcock	1. All studies analyzed for presence of needed "distinguishing features" 2. Test for publication bias
2. What is the overall effect size when using CBM to reading comprehension?	No hypothesis formulated	CBM and reading comprehension	Meta-analysis effect size (*r*)	1. Sample Size of studies>10 2.Reliabilities of measures >.70 3. Studies published on or after 1990 4. Outcome measure is a test authored by Richard Woodcock	1. All studies analyzed for presence of needed distinguishing features 2. Test for publication bias
3. What is the overall effect size when using short-term memory studies to predict basic reading skills?	No hypothesis formulated	Short-term memory and basic reading skills	Meta-analysis effect size (*r*)	1. Sample Size of studies>10 2. Reliabilities of measures >.70 3. Studies published on or after 1990 4. Outcome measure is a test authored by Richard Woodcock	1. All studies analyzed for presence of needed distinguishing features 2. Test for publication bias

4. What is the overall effect size when using short-term memory studies to predict reading comprehension?	No hypothesis formulated	Short-term memory and reading comprehension	Meta-analysis effect size (*r*)	1. Sample Size of studies>10 2. Reliabilities of measures >.70 3. Studies published on or after 1990 4. Outcome measure is a test authored by Richard Woodcock	1. All studies analyzed for presence of needed distinguishing features 2. Test for publication bias
5. What is the overall effect size when using processing speed studies to predict basic reading skills?	No hypothesis formulated	Processing speed and basic reading skills	Meta-analysis effect size (*r*)	1. Sample Size of studies>10 2. Reliabilities of measures >.70 3. Studies published on or after 1990 4. Outcome measure is a test authored by Richard Woodcock	1. All studies analyzed for presence of needed distinguishing features 2. Test for publication bias
6. What is the overall effect size when using processing speed studies to predict reading comprehension?	No hypothesis formulated	Processing speed and basic reading skills	Meta-analysis effect size (*r*)	1. Sample Size of studies>10 2. Reliabilities of measures >.70 3. Studies published on or after 1990 4. Outcome measure is a test authored by Richard Woodcock	1. All studies analyzed for presence of needed distinguishing features 2. Test for publication bias

7. What are the effect sizes of short-term memory and processing speed when they are grouped as “cognitive” and “CBM” variables when used to predict basic reading skills?	CBM will show a mildly greater effect size over cognitive processing variables when predicting basic reading skills	CBM, cognitive processing, and basic reading skills	1. Meta-analysis effect size *(r)* 2. Fisher’s r to z transformation	None	Force equal sample size for CBM and cognitive processing variables post hoc to determine the influence the larger sample size due to combining of processing speed and short-term memory variables
8. What are the effect sizes of short-term memory and processing speed when they are grouped as “cognitive” and “CBM” variables when used to predict reading comprehension?	CBM will show a mildly greater effect size over cognitive processing variables when predicting reading comprehension	CBM, cognitive processing, and reading comprehension	1. Meta-analysis effect size *(r)* 2. Fisher’s r to z transformation	None	Force equal sample size for CBM and cognitive processing variables post hoc to determine the influence the larger sample size due to combining of processing speed and short-term memory variables

used). Assumption appropriateness was accomplished by reviewing the distinguishing features of each study before including them in the analysis. The propensity for publication bias was also measured.

Research Question 2: What is the Overall Effect Size when using CBM to Predict Reading Comprehension?

The purpose of this question is to determine the overall effect size when analyzing past studies that compared CBM to reading comprehension. There wasn't a hypothesis formulated as the purpose of this question was simply to review the overall effect size between these two variables. The statistical procedure used was also meta-analysis, which also resulted in an overall *r* effect size. The assumptions for data included that all data analyzed conformed to the distinguishing features noted in the design of this study. Assumption appropriateness was accomplished by reviewing the distinguishing features of each study before including them in the analysis as well as testing for publication bias.

Research Question 3: What is the Overall Effect Size when using Short-Term Memory to Predict Basic Reading Skills?

The purpose of this question is to determine the overall effect size when analyzing past studies that compared short-term memory to basic reading skills. There wasn't a hypothesis formulated as the purpose of this question was simply to review the overall effect size between these two variables. The statistical procedure used was also meta-analysis, which also resulted in an overall *r* effect size. The assumptions for data included that all data analyzed conformed to the distinguishing features noted in the design of this study. Assumption appropriateness was accomplished by reviewing the distinguishing features of each study before including them in the analysis as well as testing for publication bias.

Research Question 4: What is the Overall Effect Size when using Short-Term Memory to Predict Reading Comprehension Skills?

The purpose of this question is to determine the overall effect size when analyzing past studies that compared short-term memory to basic reading skills. There wasn't a hypothesis formulated as the purpose of this question was simply to review the overall effect size between these two variables. The statistical procedure used was also meta-analysis, which also resulted in an overall *r* effect size. The assumptions for data included that all data analyzed conformed to the distinguishing features noted in the design of this study. Assumption appropriateness was accomplished by reviewing the distinguishing features of each study before including them in the analysis as well as testing for publication bias.

Research Question 5: What is the Overall Effect Size when using Processing Speed to Predict Basic Reading Skills?

The purpose of this question is to determine the overall effect size when analyzing past studies that compared processing speed to basic reading skills. There wasn’t a hypothesis formulated as the purpose of this question was simply to review the overall effect size between these two variables. The statistical procedure used was also meta-analysis, which also resulted in an overall *r* effect size. The assumptions for data included that all data analyzed conformed to the distinguishing features noted in the design of this study. Assumption appropriateness was accomplished by reviewing the distinguishing features of each study before including them in the analysis as well as testing for publication bias.

Research Question 6: What is the Overall Effect Size when using Processing Speed to Predict Reading Comprehension Skills?

The purpose of this question is to determine the overall effect size when analyzing past studies that compared processing speed to reading comprehension. There wasn’t a hypothesis formulated as the purpose of this question was simply to review the overall effect size between these two variables. The statistical procedure used was also meta-analysis, which also resulted in an overall *r* effect size. The assumptions for data included that all data analyzed conformed to the distinguishing features noted in the design of this study. Assumption appropriateness was accomplished by reviewing the distinguishing features of each study before including them in the analysis as well as testing for publication bias.

Research Question 7: What are the Effect Sizes of Short-Term Memory and Processing Speed when they are grouped as “Cognitive” and “CBM” Variables when used to Predict Basic Reading Skills?

The purpose of this research question is to compare the overall effect size (correlation) of CBM to cognitive processing variables when predicting basic reading skills. It was hypothesized that curriculum based measurement would have a mildly greater effect over cognitive processing when comparing these associations. This was tested by grouping the analyses of the CBM data to create a CBM grouping variable and combining the short-term memory and processing speed variables to create a “cognitive processing” grouping variable. Again, a random effects meta-analysis was the technique utilized. The overall effect sizes were correlations. Again, all studies were the same as in the previous research questions and therefore met the prior assumptions. Because these are the same studies that were previously analyzed, no new techniques to determine assumption appropriateness were used.

After the effect sizes were calculated, a secondary statistical test was used, which was a Fisher’s r to z transformation. This converts the correlation into a z correlation. The differences between those metrics were then analyzed for statistical significance. Because sample size can have an effect on the significance of measurements (Lipsey & Wilson, 2001) and because there were significantly more studies with the cognitive processing variable, a follow-up technique was used. The Fisher’s r to z transformation was run again but with equivalent sample sizes. This served as a check and balance because the sample size for the cognitive processing grouping variable was greater.

Research Question 8: What are the Effect Sizes of Short-Term Memory and Processing Speed when they are grouped as “Cognitive” and “CBM” Variables when used to Predict Reading Comprehension?

The purpose of this research question is to compare the overall effect size (correlation) of CBM to cognitive processing variables when predicting reading comprehension. It was hypothesized that curriculum based measurement would have a mildly greater effect over cognitive processing when comparing these associations. All procedures, analyses, and assumptions were identical to that of research question 7, except that the outcome variable was reading comprehension.

Summary

This chapter surveyed the methodology proposed to conduct this study. First, the population and sample of studies was discussed. Next, assignment of which studies will be picked for analysis was overviewed. Measurement techniques including latent variables and instrumentation techniques were also reviewed. The procedures indicated a timetable for the study to be developed. Finally, sample size and methods of statistical analysis were discussed.

Chapter IV

RESULTS

Overview

This chapter reveals the results of the meta-analyses. First, complications related to conducting the analysis will be overviewed. Next, the results of the analysis will be presented. Finally, the results will be summarized.

Complications

This study presented with few complications. The most significant complication seemed to be related to obtaining studies that related processing speed to reading comprehension. There were not many that were discovered that met the inclusion criteria. Furthermore, there seemed to be many more studies that looked at rapid naming ability, as opposed to visual-motor processing speed. In other words, there were more studies that looked at one’s ability to rapidly scan and verbally relay what one sees as opposed to engaging in motor speed.

Although some of the results in the studies varied, no results were eliminated. Some studies that measured processing speed showed negative associations with reading ability, likely because the construct would be inversely proportional to what was desired (that is, taking a long time to process the information and using the time as the predictor variable.) To deal with these concerns, the absolute value of the correlation for studies that related processing speed was taken to ensure the validity of the results. Transforming this data in this manner is expected to maintain the validity of the results because the correlation coefficients represent the magnitude of the relationship between two variables. In this specific case, the magnitude of the correlation remains the same but higher scores actually denote worse performance; this transformation corrects this phenomenon.

Computer Programs

Two statistical computer programs were utilized to analyze the data. First, the program Comprehensive Meta Analysis Version 2.0 (Bornstein, Hedges, Higgins, & Rothstein, 2005) was used to analyze the data from the various studies. Also, an online calculator by Lowry (2009) was used to calculate a Fisher’s r to z transformation to determine the magnitude of the differences between the CBM and cognitive processing variables.

Data Analysis

All studies used a random effects model as differences between studies were likely attributable to more than sampling error. Each research question will include a review of the studies that were selected, along with obtained data. The overall effect size (correlation) is also displayed. Afterward, as a way to check the assumptions of the underlying data, Rosenthal’s fail-safe N is also reported. The fail-safe N is the number of non-significant studies that would be needed in order for the analysis to reach non-significance to explore publication bias. Finally, a Fisher's r to z transformation was completed to determine the differences between the strengths of association between CBM and the two reading areas (basic reading skills and reading comprehension) and the cognitive processes along with the two reading skills (basic reading skills and reading comprehension). This was completed by using an online calculator (Lowry, 2009). Valentine and Cooper (2003) review Cohen's rules of thumb for determining effect size. Specifically that *r* values of .10 are small, .30 are medium, and .50 and higher are larger. Those values will be used to determine the magnitude of effect size for each research question.

Research Question 1: What is the Overall Effect Size when using CBM to Predict Basic Reading Skills?

The first research question addressed the effect size (correlation) between curriculum based measurement and basic reading skills. Thirteen studies were selected that fit the inclusion criteria. The sample size, variable names, and correlations are all reported. Additionally, the resulting effect size using Fisher's Z transformation is also reported for the interested reader, although the correlation will be the variable of interest. The results are reported in Table A1 in the appendix.

This comparison of CBM to basic reading skills resulted in a synthesis of 13 studies and a total of 55 correlations. The results of the analysis showed a large effect size (*r* = .618) between curriculum based measurement and basic reading skills. The results are summarized in Table 3.

Table 3

Meta-Analysis of Curriculum Based Measurement and Basic Reading Skills

To investigate for the presence of publication bias, Rosenthal's fail-safe n test was run. The fail-safe n is 40,401. In other words,

n of studies	n of measured variables	Correlation	Fisher's Z	p value
14	55	.626	.735	<.001

40,401 studies showing nonsignificant relationships between CBM and basic reading skills would have to be present in order for the association to reach the null hypothesis. Given that this is a very high number, there is likely no publication bias for these variables.

Research Question 2: What is the Overall Effect Size when using CBM to Predict Reading Comprehension?

The second research question addressed the effect size (correlation) between curriculum based measurement and reading comprehension. As can be seen in Table A2 in the appendix, eleven studies were selected that fit the inclusion criteria. The sample size, variable names, and correlations are all reported. Additionally, the resulting effect size using Fisher's Z transformation is also reported for the interested reader, although the correlation will be the variable of interest.

The comparison of CBM to reading comprehension resulted in a synthesis of eleven studies and a total of 23 correlations. The results of the analysis showed a large effect size (r = .636) between curriculum based measurement and reading comprehension. The results are summarized in Table 4.

Table 4

Meta-Analysis of Curriculum Based Measurement and Reading Comprehension (using a cloze-based assessment)

n of studies	n of measured variables	Correlation	Fisher's Z	p value
11	23	.636	.751	<.001

The fail-safe n for this analysis is 6,466. In other words, 6,466 studies showing nonsignificant relationships between CBM and basic reading skills would have to be present in order for the association reach the null hypothesis. Although not as high as noted in research question 1, this is still a very high number; therefore, there is likely no publication bias for these variables.

Research Question 3: What is the Overall Effect Size when using Short-Term Memory to Predict Basic Reading Skills?

The third research question addressed the effect size (correlation) between short-term memory and basic reading skills. As can be seen in Table A3 in the appendix, 14 studies were selected that fit the inclusion criteria. The sample size, variable names, and correlations are all reported. Additionally, the resulting effect size using Fisher’s Z transformation is also reported for the interested reader, although the correlation will be the variable of interest.

The comparison of short-term memory to basic reading skills resulted in a synthesis of 14 studies and a total of 49 correlations. The results of the analysis showed a moderate effect size (r = .390) between short-term memory and basic reading skills. The results are summarized in Table 5.

Table 5

Meta-Analysis of Short-Term Memory and Basic Reading Skills

n of studies	n of measured variables	Correlation	Fisher's Z	p value
14	49	.390	.412	<.001

The fail-safe n for this analysis is 13,450. In other words, 13,450 studies showing nonsignificant relationships between short-term memory and basic reading skills would have to be present in order for the association reach the null hypothesis. Given that this is a very large number, there is likely no publication bias for these variables.

Research Question 4: What is the Overall Effect Size when using Short-Term Memory to Predict Reading Comprehension Skills?

The fourth research question addressed the effect size (correlation) between short-term memory and reading comprehension. As can be seen in Table A4 in the appendix, nine studies were selected that fit the inclusion criteria. The sample size, variable names, and correlations are all reported. Additionally, the resulting effect size using Fisher's Z transformation is also reported for the interested reader, although the correlation will be the variable of interest.

This comparison of short-term memory to reading comprehension resulted in a synthesis of nine studies and a total of 35 correlations. The results of the analysis showed a moderate effect size (r = .387) between short-term memory and reading comprehension. The results are summarized in Table 6.

Table 6

Meta-Analysis of Short-Term Memory and Reading Comprehension Skills (using a cloze-based assessment)

n of studies	n of measured variables	Correlation	Fisher's Z	p value
8	35	.387	.424	<.001

The fail-safe n for this analysis is 8,048. In other words, 8,048 studies showing nonsignificant relationships between short-term memory and reading comprehension would have to be present in order for the association reach the null hypothesis. Given that this is a very large number, there is likely no publication bias for these variables.

Research Question 5: What is the Overall Effect Size when using Processing Speed to Predict Basic Reading Skills?

The fifth research question addressed the effect size (correlation) between processing speed and basic reading skills. As can be seen in Table A5 in the appendix, 17 studies were selected that fit the inclusion criteria. The sample size, variable names, and correlations are all reported. Additionally, the resulting effect size using Fisher's Z transformation is also reported for the interested reader, although the correlation will be the variable of interest.

This comparison of processing speed to basic reading skills resulted in a synthesis of 17 studies and a total of 123 correlations. The results of the analysis showed a moderate effect size (r = .405) between processing speed and basic reading skills. The results are summarized in Table 7.

Table 7

Meta-Analysis of Processing Speed and Basic Reading Skills

n of studies	n of measured variables	Correlation	Fisher's Z	p value
17	123	.405	.430	<.001

The fail-safe n for this analysis is 76,694. In other words, 77,694 studies showing nonsignificant relationships between processing speed and basic reading skills would have to be present in order for the association reach the null hypothesis. Given that this is a very large number, there is likely no publication bias for these variables.

Research Question 6: What is the Overall Effect Size when using Processing Speed to Predict Reading Comprehension Skills?

The sixth research question addressed the effect size (correlation) between processing speed and reading comprehension. As can be seen in Table A6 in the appendix, seven studies were selected that fit the inclusion criteria. The sample size, variable names, and correlations are all reported. Additionally, the resulting effect size using Fisher's Z transformation is also reported for the interested reader, although the correlation will be the variable of interest.

The comparison of processing speed to reading comprehension skills resulted in a synthesis of seven studies and a total of 38 correlations. The results of the analysis showed a moderate effect size (*r* = .433) between processing speed and basic reading skills. The results are summarized in Table 8.

Table 8

Meta-Analysis of Processing Speed and Reading Comprehension Skills (using a cloze-based assessment)

n of studies	n of measured variables	Correlation	Fisher's Z	p value
7	38	.433	.463	<.001

The fail-safe n for this analysis is 7,321. In other words, 7,321 studies showing nonsignificant relationships between processing speed and reading comprehension would have to be present in order for the association reach the null hypothesis. Given that this is a large number, there is likely no publication bias for these variables.

Research Question 7: What are the Effect Sizes of Short-Term Memory and Processing Speed when they are grouped as "Cognitive" and "CBM" Variables when used to Predict Basic Reading Skills?

This research question primarily addresses what the overall effect sizes are when a variable known as "CBM" is compared with the variable known as "cognitive processes" (combining both short-term memory and processing speed). Overall, CBM demonstrated a strong effect size (r = .626) when correlating with basic reading skills. Cognitive processing demonstrated a moderate effect size (r = .402). These results are summarized in Table 9.

Table 9

The Association of CBM and Cognitive Processing Variables to Basic Reading Skills

Predictor Variable	n of analyses	Correlation	Fisher's Z value	p value
CBM	57	.626	.722	<.001
COG	172	.402	.425	<.001

To analyze the difference between associations, a two-tailed Fisher's r to z transformation test was conducted. The results revealed the difference between CBM and cognitive processing was statistically significant; $z(228) = 1.98$ $p = .0477$. To determine the effect of sample size on the difference (given that the COG variable is actually a synthesis of both short-term memory and processing speed), an analysis was done assuming that the sample size of analyses was evenly distributed. The results revealed that the associations continued to be statistically discrepant $z(228) = 2.30$, $p = .0214$.

Research Question 8: What are the Effect Sizes of Short-Term Memory and Processing Speed when they are grouped as "Cognitive" and "CBM" Variables when used to Predict Reading Comprehension?

This research question primarily addresses what the overall effect sizes are when CBM is compared with cognitive processes (combining both short-term memory and processing speed). Overall, CBM demonstrated a strong effect size ($r = .636$) when correlating with reading comprehension. Cognitive processing demonstrated a moderate effect size ($r = .410$). These results are summarized in Table 10.

Table 10

The Association of CBM and Cognitive Processing Variables to Reading Comprehension (using a cloze-based assessment)

Predictor Variable	n of analyses	Correlation	Fisher's Z value	p value
CBM	23	.636	.751	<.001
COG	73	.410	.436	<.001

To analyze the difference between associations, a two-tailed Fisher's r to z transformation test was conducted. The results revealed that the associations were not significantly discrepant; $z(95) = 1.25$, $p = .2113$. To determine the effect of sample size on the difference (given that the COG variable is actually a synthesis of both short-term memory and processing speed), an analysis was done assuming that the sample size of analyses was evenly distributed. The results revealed that the associations were still not significantly discrepant $z(95) = 1.50$, $p = .1336$.

Summary

The preceding highlighted both complications with the study and also the data analysis employed. The primary complication of the study was the lack of studies that related processing speed to reading comprehension. Another complication was the increased presence of studies that seemed to deal more with rapid naming ability than visual-motor processing speed. The results indicated that CBM is strongly associated with both basic reading skills and reading comprehension. Short-term memory and processing speed skills were both moderately correlated with basic reading skills and reading comprehension. When CBM was compared to a synthesis of both short-term memory and processing speed, which were subsequently identified as a "cognitive processing variable", the results were upheld that CBM was strongly related to basic reading skills and reading comprehension, while the cognitive processing variable was moderately related to both basic reading skills and reading comprehension. A subsequent analysis where the correlations of the CBM and cognitive processing variables were compared to both basic reading skills and reading comprehension failed to show significant differences, identifying that one variable was not a statistically stronger predictor of either basic reading skills or reading comprehension.

Chapter V

DISCUSSION

Overview

The purpose of this study was to review the relationships between three predictor variables (Curriculum Based Measurement, Short-Term Memory, and Processing Speed) and two outcome variables (Basic Reading Skills and Reading Comprehension.) The focus of this study was derived in response to the mixed debate on the utility of using cognitive or neuropsychological assessment as relevant and important for identifying learning disabilities.

Again, the field has been replete with controversy with regard to the aforementioned point. On the one hand, there continues to be literature published identifying that use of these techniques are seemingly unnecessary for the identification of learning disabilities (Reschly & Yssledyke, 2002; Reschly, 2005). Some have argued that the only “cognitive process” that has been shown to have any impact on achievement, specifically reading, are phonological processes (Gresham, Restori, & Cook, 2008). The argument has also been made that relating cognitive processes to intervention, also known as an aptitude treatment interaction (ATI), yields little fruit (Reschly & Yssledyke, 2002). In sharp contrast, other researchers have identified that the identification of cognitive processes is important and necessary in a comprehensive evaluation (Semrud-Clikeman, 2005;

Miller, 2007; Mather & Jaffe, 2002) especially in conjunction with assessment methods such as curriculum based measurement that can be used in a response to intervention framework (Hale, Kaufman, Naglieri, & Kavale, 2006). Even the tenet of the aforementioned ATI phenomenon has been addressed in relation to the types of research that has been conducted (Hale & Fiorello, 2004) and that ATIs have indeed been established between cognitive skills and academic achievement (Naglieri & Johnson, 2000; Fuchs & Young, 2006). Given the changes in the Individuals with Disabilities Education Act (2004) and the very flexible latitude allowed to identify learning disabilities indicated, which allow for both a pattern of strengths and weaknesses or response to intervention (Individuals with Disabilities Education Act, 2004), little guidance is provided to practitioners with how to identify specific learning disabilities.

Although many studies have been done that have related both CBM and cognitive processing to reading, there is currently a dearth of research that has looked at both of these measures simultaneously. Therefore, looking at the relationships of these variables to reading seems to be a logical endeavor.

This particular study sought to answer eight research questions. Three questions sought to synthesize research relating CBM, short-term memory, and processing speed to basic reading skills. Three questions sought to synthesize research relating CBM, short-term memory, and processing speed to reading comprehension. The seventh question sought to compare the association of CBM to basic reading skills and cognitive processes, again synthesizing the aforementioned short-term memory and processing speed variables into a construct known as "cognitive processing" to basic reading skills. Finally, the eighth question sought to compare the association of CBM to reading comprehension and cognitive processes to reading comprehension.

Each research question was conducted via a meta-analysis. Each study chosen had to meet the criteria for inclusion and discovered studies were only discarded if they did not meet the criteria. In the event that studies had only some variables that did not meet the inclusion criteria, then those variables were discarded.

Research Questions and Hypotheses

Research Question 1: What is the Overall Effect Size when using CBM to Predict Basic Reading Skills?

The first research question analyzed the relationship between CBM and basic reading skills. The results showed an overall strong effect between CBM and basic reading skills (r = .626). This is not surprising as many CBM techniques are very similar to both decoding and word reading. Oral reading fluency seeks to measure the number of words one can read in one minute (Good, Knutson, & Shinn, 1992). Nonsense Word Fluency analyzes phoneme/grapheme relationships with the fluency with which one can read nonsense consonant/vowel/consonant

(CVC) words. Phoneme Segmentation Fluency analyzes how well one can hear the various sounds that make up words (Brunsman, 2005). All of these skills (particularly oral reading fluency) are really not dissimilar to the ability to read real words or to adequately decode words that are not real.

The notion of using CBM as a method to assess the building blocks of reading skills seems well founded. They are quick, easy measurements to use and can identify where a student may be breaking down and may need intervention (Burns et al., 2006). An example might be that a poor ORF score might signal the need for repeated readings, whereas a poor NWF score might signal the need for more explicit training in phoneme/grapheme relationships.

Research Question 2: What is Overall Effect Size when using CBM to Predict Reading Comprehension?

The second research question sought to analyze the relationship between CBM and reading comprehension. Overall, a strong relationship was found relating CBM to reading comprehension. Although the relationship was similar to that of basic reading skills, the stronger relationship for reading comprehension was a bit more surprising. Although certainly the ability to read more words correctly makes sense, many other techniques go into reading comprehension, including executive functioning skills and linguistic skills (Feifer & Della Toffalo, 2007).

The results, however, do make sense. First, it’s important to note that with the exception of a MAZE variable in one study (which does look somewhat at comprehension), only two variables did not use number of words read correctly per minute as their CBM measure. Both of those variables were noted in Vadasy et al., 2006. The correlation values for those two variables were .26 and .29, which were among the weakest correlations discovered. Therefore, it is surmised that if one could read fluently with automaticity, more cognitive resources can be “freed up” for understanding. This fits with the problem solving literature that has noted the importance of skills such as working memory as it relates to reading comprehension (Feifer & Della Toffalo, 2007).

Another important consideration for the stronger effect size is the type of technique used to assess reading comprehension. In each case, the technique was a cloze reading technique, again requiring the examinee to fill in the missing word that logically completes the passage. One possibility that exists is that those examinees with good oral reading fluency may do well with logically choosing the word that fits. There is evidence of this in the research (Shinn, 1992). Although Shinn also notes strong correlations between literal comprehension and CBM, the correlation between inferential comprehension and CBM was moderate. More research is needed with other types of comprehension assessments where examinees are required to answer both literal and inferential comprehension questions and correlating those skills to CBM.

Research Question 3: What is the Overall Effect Size when using Short-Term Memory to Predict Basic Reading Skills?

The third research question sought to analyze the relationship between short-term memory and basic reading skills. Overall, a moderate relationship was found relating short-term memory to basic reading skills. It is interesting to note that the range of correlations in the meta-analysis was very large (ranging from -.07 to .675).

There are a variety of reasons that can account for this significant span. First, it is important to remember that short-term memory is very broad. Again, the Cattell-Horn-Carroll (CHC) theory indicates that there are two very different narrow abilities, memory span and working memory, that fall under short-term memory. Furthermore, as indicated in Dehn (2008), the notion of working memory is very broad, much more so than CHC theory covers. Dehn cites, for example, Baddley’s model, which emphasizes three components of working memory: the phonological loop, the visual-spatial sketchpad, and the central executive.

Secondly, the results in this particular analysis presented with two studies that were largely absent in other studies; the skills of children who are normally reading vs. those who are not. In the Bowey et al. (1992) study, the relationship between reading and digit span backward was moderate for normally achieving students (r = .320), but weakly inversely related for those who had learning delays (r = -.05). Furthermore, in the Katzir et al. (2006) study, again the relationships were different between those who were nondisabled (r = .5 for memory for digits and word attack for the nondisabled and r = .003 for the disabled). This, however, was not a consistent pattern. For example, in the same study, the correlation for memory for digits and word identification was only .030. Nevertheless, the significant differences in these areas absolutely indicate that the relationship between short-term memory and reading requires further research for both the disabled and nondisabled populations.

It is important to note that even with the aforementioned considerations taken into account, the relationship between short-term memory and basic reading skills still shows a moderate association. This correlates with past problem solving research that has identified the importance of short-term memory in the acquisition of basic reading skills. This relationship makes sense; if a student has short-term memory deficits, they may have the ability to decode certain letter patterns, but when working on longer words, they may forget what the initial sounds were, thereby confounding the blending process (Dehn, 2008). It makes further sense that there could be a discrepancy related to the associations between disabled and nondisabled readers. As indicated in the research (Hale & Fiorello, 2004; Mather & Wendling, 2005; Flanagan, Ortiz, Alfonso & Mascolo, 2006, Feifer & Della Toffalo, 2007), there could be a myriad of reasons as to why a student may have trouble reading…it is not simply relegated to short-term memory. Therefore, students who are disabled may have their disability with one of the other psychological/neuropsychological processes. Again, further research in this area is important to address these additional issues.

Research Question 4: What is the Overall Effect Size when using Short-Term Memory to Predict Reading Comprehension Skills?

The fourth research question sought to analyze the relationship between short-term memory and reading comprehension. Overall, a moderate relationship was found relating short-term memory to reading comprehension.

Similar to the third research question, there existed somewhat of a wide range of correlations (.02-.62), although not quite as broad. The same issues seem to be present for short-term memory and reading comprehension as there were with short-term memory and basic reading skills. That is, there is a broad scope of what constitutes "short-term memory." Furthermore, the discrepancy between the reading disabled and the non-disabled in the Katzir et al., (2006) study was also prevalent (r = .02 for disabled and .40 for nondisabled), showing again the importance of further research in this area.

Nevertheless, the moderate relationship between short-term memory and reading comprehension also makes sense and seems to correlate to the past problem solving research. Certainly, when one is reading, one must be able to hold the information in immediate awareness in order to make sense of it (Dehn, 2008). Although according to CHC theory, this may be more related to long-term storage and retrieval (Glr), one must still use information that is in short-term memory to make the transfer. This is supported by Mather and Wendling (2005), who indicate, “If decoding is labored, then fluency is reduced, and greater demands are placed on working memory, diminishing comprehension” (p. 279).

Research Question 5: What is the Overall Effect Size when using Processing Speed to Predict Basic Reading Skills?

The fifth research question sought to analyze the relationship between processing speed and basic reading skills. Overall, a moderate relationship was found relating processing speed to basic reading skills.

As indicated with short-term memory, there was a wide range of correlations that were present between processing speed and basic reading skills (from .06-.70). Similar to short-term memory, one issue that was present was the inclusion of both visual-motor processing speed as well as rapid naming under the overarching heading of “processing speed.” Even within the “rapid naming” (RAN) category, there seemed to be a stronger relationship of rapidly naming digits and letters to reading than colors or objects. For example, in the Mariko-Doi (1996) study, the naming of digits and letters yielded correlation coefficients that ranged from .48-.70. However, the rapid naming of pictures yielded a range of .17-.29. This may provide further evidence as to why CBM seems to yield larger associations to reading than some of the cognitive processes that have been studied. It is important to recall that one particular CBM measure is an identical task to the rapid naming of letters; Letter-Naming Fluency on the DIBELS measures how many letters a child can name in 60 seconds.

Despite the finding that naming of digits and letters seem to be stronger indicators to reading, it is important to note that this was not exclusionary to other factors. For example, the McBride-Chan and Kail (2002) study identified stronger correlations when comparing visual-motor tasks to basic reading skills (r = .45 between cross out and word identification; r = .57 between visual matching and word identification.) Overall, it is clear that the rate at which one can process and respond to information has shown to have an association to basic reading skills.

Research Question 6: What is the Overall Effect Size when using Processing Speed to Predict Reading Comprehension Skills?

The sixth research question sought to analyze the relationship between short-term memory and reading comprehension. Overall, a moderate relationship was found relating processing speed to reading comprehension.

As noted with short-term memory and reading as well as processing speed to basic reading skills, there was a wide range of correlations reported across studies (.06-.77), although there were less studies relating processing speed to reading comprehension. Furthermore, only two of the studies (a total of four variables) looked at visual-motor processing speed related to reading comprehension (McGrew & Woodcock, 2001; McGrew, Werder & Woodcock, 1991) and these were actually correlations that were taken from the technical manuals used in the norming of the WJ-R and WJ-III. The relationships that were discovered for these variables showed moderate associations between visual-motor speed and reading comprehension (range of .380-.518). Clearly, further research is needed identifying the impact of visual-motor processing speed on reading comprehension. Nevertheless, the moderate overall correlation between processing speed and reading comprehension suggests that the rate at which one processes information does relate to overall reading comprehension.

Research Question 7: What are the Effect Sizes of Short-Term Memory and Processing Speed when they are grouped as “Cognitive” and “CBM” Variables when used to Predict Basic Reading Skills?

The purpose of the seventh research question was to group the short-term memory and processing speed variables together under an over-arching “cognitive” variable and compare that to the CBM variable when predicting basic reading skills. It was hypothesized that CBM would show a slightly larger effect size (correlation) than the cognitive factors when relating to basic reading skills. This hypothesis was based not only on outcomes based on the initial review of the literature relating CBM to reading but also related to identifying how many cognitive variables have been shown to influence basic reading skills (Evans et al., 2001; Flanagan et al., 2006). This hypothesis was supported as CBM showed a strong effect size (r = .626) and cognitive processing showed a moderate effect size (r = .402).

The associations were then compared to each other using a Fisher’s r to z transformation, the difference between the two associations was not statistically significant ($z(228) = 1.98$, p = .0477). This indicates that even though the magnitude of the correlations is in favor of CBM (strong vs. moderate correlation), one was still not significantly greater than the other. This indicates that one variable does not predict significantly more than the other.

An important caveat is that the number of variables was greater for cognitive processing as both short-term memory and processing speed were combined; the larger comparison sample size therefore needs to be taken into consideration. To test the impact of sample size, a test was conducted assuming an equal distribution between the CBM and cognitive variables, which then led to a statistical discrepancy between CBM and cognitive processing ($z(226) = 2.19$, $p = .0285$.) Therefore, the absence of a statistical discrepancy is related to the sample size generated by fusing short-term memory with processing speed. Although the overall metric is a correlation and only seeks to look at the relationship between two variables at given points in time and in no way can imply causation, this data should be given due consideration in light of claims by some that assessment of cognitive variables is not important or germane to identifying learning disabilities (Reschly & Yssledyke, 2002; Reschly, 2005) or that phonological processing is the only processing variable shown to relate to reading (Gresham et al., 2008).

Research Question 8: What are the Effect Sizes of Short-Term Memory and Processing Speed when they are grouped as “Cognitive” and “CBM” Variables when used to Predict Reading Comprehension?

The purpose of the eighth research question was to again take the cognitive processing grouped variable (the combination of short-term memory and processing speed) and compare it with CBM to predict reading comprehension. It was hypothesized that CBM would show a slightly larger effect size (correlation) than the cognitive factors when relating to reading comprehension skills, again based on the initial review of the literature.

This hypothesis was also supported as CBM showed a strong effect size (r = .751) and cognitive processing showed a moderate effect size (r = .410). Again, surprisingly, when compared via a Fisher's r to z transformation, the results were not shown to be significantly discrepant ($z(95) = 1.25$, p = .2113). Again, this is important to be considered in light of the claims of the irrelevance of the utility of cognitive assessment to assess academic achievement (Reschly & Yssledyke, 2002; Reschly, 2005) and the claims, again, that phonological processing is the only cognitive processing variable shown to relate to reading (Gresham et al., 2008). Despite the importance of this consideration, one important caveat is that the variables of short-term memory and processing speed were combined, which did increase the sample size. To test the impact of sample size, a test was conducted assuming an equal distribution between the CBM and cognitive variables, which still did not show a statistical discrepancy between CBM and cognitive processing when predicting reading comprehension ($z(95) = 1.5$, p = .1336.) This is a very important consideration as it identifies that although CBM does have a stronger relationship to reading comprehension, the association is not significantly stronger than cognitive processing, even with the sample size controlled. As stated earlier, however, it must also be remembered that reading comprehension was primarily assessed through a cloze technique and more research is needed for the use of tests requiring the examinee to answer comprehension questions directly.

Limitations

The preceding research study did present with limitations. One limitation of the study was, due to limited resources, the lack of external coders used in selecting studies. Various texts on meta-analysis (e.g. Lipsey & Wilson, 2001) indicate that a best practice in meta-analysis is to identify the parameters of the study and allow others to determine how closely a study matches the selected criteria. However, there are meta-analyses that have not used coding schemes (VanVoorhis, 2003) or have used their own criteria in coding their studies (Frazier, Demaree, & Youngstrom, 2004). Although this issue was addressed by specifying very clear inclusion criteria and not excluding any study when all inclusion criteria were met, the absence of other coders is nevertheless a limitation to this study.

Another limitation to this study is the very narrow use of test batteries to assess both basic reading skills and reading comprehension. The purpose of this was to ensure that the same task demands were used when viewing the outcome variable. Although this strengthens the statistical approach, there are limitations to this framework. For example, the Woodcock tests primarily use cloze as the primary method to measure reading comprehension. Other tests, such as the Wechsler Individual Achievement Test-2nd Edition (WIAT-II) (Wechsler, 2001), look at reading comprehension differently. They require the student to read a longer story and then ask both literal and inferential comprehension questions. Few studies across both the CBM and cognitive processing variables used this type of test and therefore those that did were excluded from the analysis. Quite possibly, the nature of using a cloze assessment may have impacted the results as well. More research is needed that use the aforementioned tests as well as others that require examinees to answer direct comprehension questions after reading selected passages.

Another limitation of this study related to sample size. Only seven studies were found that related processing speed to reading comprehension that met the inclusion criteria. Fortunately, the studies consisted of many different variables, which made for more comparisons. Furthermore, the number of comparisons for this variable exceeded others even though there were fewer studies. Nevertheless, it will be important to continue to conduct research that relates processing speed to reading given that moderate associations are present between these two variables.

Another limitation to the research was the difficulty with separating out subject variables and analyzing them further. For example, it was noted in a few studies that short-term memory seemed to play a stronger role when viewed in tandem with the non-disabled rather than disabled readers. Unfortunately, not enough studies separated important factors, such as sex, age of the participants (many grouped them together) or disability status. Further research is needed to explore these areas with better definition.

Another limitation was the fusion of various narrow abilities that were subsumed by the construct of interest. Specifically, short-term memory encompassed both memory span skills and working memory skills. Similarly, processing speed skills included both visual-motor speed skills as well as rapid naming skills. All of these more “narrow” skills do have some differences between them, but the limited breadth of studies required analysis of the cognitive processing variables in a broader sense.

A final limitation to the study was the lack of research available for the other areas identified as possible for students to be identified with learning disabilities under IDEA (IDEA, 2004), including reading fluency, math computation, math problem solving, written expression, listening comprehension, and oral expression. Ironically, the dearth of research seemed to reside primarily with CBM, which has been argued by many to be the preferred method of assessment for the identification of learning disabilities. Clearly more research is needed relating CBM to these other areas to determine the efficacy of using this framework as necessary and important for the identification of learning disabilities in these areas.

Implications for the Practice of School Psychology

The preceding research has multiple implications for the practice of school psychology. As indicated, one of the most important implications is from the research perspective. Specifically, more research needs to be done with CBM relating to math, writing, and oral language.

Nevertheless, an important question for practitioners and one that has been central to the scope of this study is, “Is it relevant to use measures of cognitive or neuropsychological processing when assessing for a specific learning disability?” Although this has been something that has been debated since RTI has gained increasing popularity, the information in the literature review has addressed this debate. For example, although Reschly and Yssledyke (2002) have identified that aptitude treatment interactions have not been found, other research has begun to unearth those important ATIs (Naglieri & Johnson, 2000; Fuchs & Young, 2006). Others have focused on the importance of these assessments as specific and relevant to the identification of learning disabilities (Hale & Fiorello, 2004; Feifer & Della Toffalo, 2007; Miller, 2007; Semrud-Clikeman, 2005).

Although the preceding research was primarily correlational in nature, the findings suggest that it is likely premature to take such a firm stance that cognitive and/or neuropsychological assessment is superfluous to the evaluation for SLD. First, although CBM presented with strong associations with reading and the cognitive processing variables (short-term memory and processing speed) only presented moderate relationships, one must bear in mind that the scope of the CBM variables was very narrow; most of them required rapid recall of letters, sounds, or words. The scope of the short-term memory and processing speed variables were much broader. Examples of this include the various types of short-term memory that are present, including auditory vs. visual short term memory or memory span vs. working memory. The same holds true for processing speed, given the various types of processing speed that are present, such as visual-motor speed vs. rapid naming, or rapid naming of objects vs. letters, etc.

Another important consideration is the breadth of cognitive and neuropsychological abilities. CHC theory currently identifies seven (nine if one includes reading, writing, and math) broad cognitive abilities. Subsumed under these broad abilities are about 70 narrow abilities (Flanagan & Mascolo, 2005). Many of these abilities may relate, in some way, to achievement. Furthermore, it can be the dysfunction of any of these skills that may lead to problems with achievement. Even the moderate correlations unearthed in this assessment are important. Problems with reading (or math, writing, or language) have reasons related to them and, subsequently, their exploration seems still to be important and relevant. If only two psychological processing variables have shown a moderate degree of prediction of basic reading skills and reading comprehension, clearly more research is needed before the recommendations of Reschly and Yssledyke (2002) can be given due consideration.

The lack of ATIs as cited by Reschly and Yssledyke above, while under scrutiny, is important nevertheless. It is important for practitioners to start monitoring interventions if they are based in any way to a student’s cognitive strengths and weaknesses. If the assessments offered by practitioners yield little fruit in the way of efficacious treatment recommendations, then indeed the time engaged by the practitioner in looking at the underlying cognitive strengths and weaknesses is likely not well spent.

Future Directions for Research

The results of this study implied important directions for future research. First, only a few studies in this study compared the performance of reading disabled vs. nondisabled students. A quick glance at the results suggests that the importance of cognitive variables such as short-term memory related to reading may hold more relevance to the nondisabled over the disabled population. The smaller sample sizes within those studies and smaller number of studies overall indicate this to be an important area for further research.

An area of concern with this research was also the lack of studies that looked at other special populations. For example, students who sustain closed head injuries may have other problems that interfere with reading that may require specific assessment techniques. According to Semrud-Clikeman, Kutz, and Strassner (2005), damage to certain areas can certainly present with consequences to reading. For example, damage to the temporal lobe may relate to challenge with learning new information. Specifically, they comment, “Damage to this region can be related to problems with emotional control, inappropriate emotional responses, and impulse control” (p. 430). Another example might be the student with an executive functioning deficit. According to Feifer and Della Toffalo (2007), “The cognitive culprits responsible for a host of reading comprehension difficulties are a constellation of higher-level problem solving skills known as executive function skills” (p. 121). The subject of interest for this study has been the identification of learning disabilities. However, an important future direction will be to conduct further studies similar to that of Katzir et al. (2006) that investigate those variables which seem most sensitive for the prediction reading, math, writing, or language problems among participants diagnosed with these various disorders.

The analysis of reading comprehension is another important future direction for this research. This study only allowed the WRMT and WJ tests to be used, hence only allowing for a cloze procedure when engaging in reading comprehension. Future analyses of this caliber should also be conducted where the examinees are asked direct comprehension questions (both literal and inferential) related to the passages they have read. Although there is some evidence of the relationship of CBM to these types of tasks (Shinn, 1992), more of these types of techniques are needed in the research literature. In fact, one may consider analyzing the relationship of CBM and cognitive processing variables to both cloze reading techniques and direct questioning comprehension techniques to see if there is a difference. This is important given that both types of techniques are considered to be satisfactory when used to identify disabilities in reading comprehension.

Another future direction will be not only to increase the number of studies looking at math computation, math problem solving, oral language, and written expression as they relate to CBM, but also using published normed reference tests as a basis for comparison. Furthermore, those same tests should be used when assessing different cognitive skills, so that the scope of other learning disability areas under IDEA 2004 can be equally assessed both with cognitive processing and CBM as predictor variables.

As stated earlier, looking at subject variables continues to be an important future direction for research. Although some studies look at the influence of sex when assessing academic achievement, most studies tend to combine males and females in their samples. The same is true of different ages. Conducting further studies like this one but looking at variables such as sex and age as moderator variables may provide more information on the power that these predictor variables have when predicting reading (or other achievement areas). The research of Evans et al. (2001) is relevant, as they indicated that certain cognitive variables, such as auditory processing, are more important at the earlier ages for predicting reading than at the later ages, where background knowledge takes a greater role. It's possible that students who have disabilities in some cognitive areas, such as oral language or long-term memory, may not see the consequences of these disabilities until later ages where their importance is more strongly related to achievement.

Another important future direction is to look at the research for other types of cognitive and neuropsychological variables. This may include skills such as visual-spatial processing, background knowledge, or executive functioning. Only two "processing" variables were included in this study and clearly these types of analyses should be taking place with all cognitive/neuropsychological variables that hold their importance with predicting reading, as well as math and writing.

A final important future direction is to increase the type of research more narrowly with the varying cognitive variables. For example, more research comparing memory span elements to reading and then working memory elements to reading may provide direction that one type of short-term memory is more important than another. The same is true for processing speed. Although the research indicates that visual-motor processing speed is relevant to reading, the same is true for rapid naming. In other words, parsing out the cognitive processing variables further may provide more information on the narrow abilities that either well associate or poorly associate to reading, writing, math, or language skills.

Summary

This section explored the implications of the eight research questions posed in this study. They included examining the relationships of CBM to basic reading skills and reading comprehension, short-term memory skills to basic reading skills and reading comprehension, processing speed skills to basic reading skills and reading comprehension, and the relationship of CBM to cognitive processing when predicting basic reading skills and reading comprehension. The results revealed strong correlations between CBM to basic reading skills to reading comprehension and moderate correlations between cognitive processing variables (both short-term memory and processing speed) to basic reading skills and reading comprehension. The difference between correlations of CBM and cognitive processing to both basic reading skills and reading comprehension were non significant. The limitations of the study, implications for school psychology, and future directions for research were all discussed.

The field of school psychology continues to debate the merit of cognitive and neuropsychological assessment as relevant to the identification of specific learning disabilities. This study has found relationships for both CBM and cognitive processing when relating to reading ability. Future research is needed to expand on this research and identify those factors that make learning difficult for children and those factors that can help those who are struggling to reach success.

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Appendix
Studies, Variables, and Statistics included in the Meta-Analysis

Table A1
Studies comparing CBM to Basic Reading Skills

Study	Sample Size	CBM variable	Basic Reading Skills Variable	Correlation	Fisher's Z	p-Value
Ardoin et al., 2004	75	MAZE	LWI	.430	.460	<.001
	77	CBM Median	LWI	.690	.848	<.001
	77	Single Passage	LWI	.620	.725	<.001
Elliot & Tollefson, 2007	75	IPA	WID	.470	.510	<.001
	75	LNF	WID	.710	.887	<.001
	75	PSA	WID	.450	.485	<.001
	75	SNF	WID	.620	.725	<.001
Fuchs, Fuchs, & Compton, 2004	151	NWF fall	WID	.580	.662	<.001
	151	NWF spr	WID	.640	.758	<.001
	151	NWF fall	WAT	.500	.549	<.001
	151	NWF spr	WAT	.510	.563	<.001
	151	WIF fall	WID	.770	1.020	<.001
	151	WIF spr	WID	.820	1.157	<.001
	151	WIF fall	WAT	.590	.678	<.001
	151	WIF spr	WAT	.520	.576	<.001
Hosp & Fuchs, 2005	29	CBM-gr 1	WID	.910	1.528	<.001
	30	CBM-gr 2	WID	.880	1.376	<.001
	30	CBM-gr 3	WID	.880	1.376	<.001
	29	CBM gr 4	WID	.730	.929	<.001
	29	CBM-gr 1	WAT	.710	.887	<.001
	30	CBM-gr 2	WAT	.820	1.157	<.001
	30	CBM-gr 3	WAT	.820	1.157	<.001
	29	CBM-gr 4	WAT	.720	.908	<.001

Sofie & Riccio, 2002	40	CBM	WID	.650	.775	<.001
	40	CBM	WAT	.640	.758	<.001
Speece & Ritchey, 2005	276	LNF fall	BRS	.240	.245	<.001
	276	LNF Jan	BRS	.470	.510	<.001
	276	ORF Jan	BRS	.500	.549	<.001
Hills, 2005	126	CBM & WID	WID	.830	1.188	<.001
Caffrey, 2000	25	CBM intercept-K CBM intercept-1	WAT	.706	.879	<.001
	95	CBM slope K CBM slope 1	WAT	.673	.816	<.001
	25		WAT	.418	.445	.037
	95		WAT	.495	.543	<.001
Miller, 2001	30	CBM	WID	.800	1.099	<.001
Denton, Cianco, & Fletcher, 2006	182	ORF	LWI	.790	1.071	<.001
	182	ORF	WAT	.670	.811	<.001
Vadasay, Sanders, & Petyon, 2006	36	LNF pretest	ACC	-.100	-.100	.564
	36	LNF posttest	ACC	.570	.648	<.001
	21	LNF post-1	ACC	.640	.758	.001
	36	PSF pre	ACC	.010	.010	.954
	36	PSF post	ACC	.500	.549	.002
	21	PSF post-1	ACC	.480	.523	.026
	36	NWF pre	ACC	-.130	-.131	.453
	36	NWF post	ACC	.530	.590	.001
	21	NWF post-1	ACC	.640	.758	.001
Chard et al., 2008	668	ORF	WID GR 1	.620	.725	<.001
	525	ORF	WID GR 2	.590	.678	<.001

	425	ORF	WID GR 3	.540	.604	<.001
	668	ORF	WAT GR 1	.580	.662	<.001
	525	ORF	WAT GR 2	.530	.590	<.001
	425	ORF	WAT GR 3	.530	.590	<.001
Spear-Swerling, 2006	61	ORF	WID	.600	.693	<.001
	61	ORF	WAT	.730	.929	<.001
Neddenriep et al., 2006	22	CBM 4th	Br. Read	.837	1.211	<.001
	29	CBM 5th	Br. Read	.870	1.333	<.001

Table A2

Studies Comparing CBM to Reading Comprehension (using a cloze-based assessment)

Study	Sample Size	CBM variable	Reading Comprehension Variable	Correlation	Fisher's Z	p-Value
Ardoin et al., 2004	75	MAZE	PC	.310	.321	.007
	77	CBM-Median CBM Single	PC	.690	.848	<.001
	77	Passage	PC	.420	.448	<.001
Hosp & Fuchs, 2005	29	CBM-gr 1	PC	.790	1.071	<.001
	30	CBM-gr 2	PC	.830	1.188	<.001
	30	CBM-gr 3	PC	.840	1.221	<.001
	29	CBM gr 4	PC	.820	1.157	<.001
Sofie & Riccio, 2002	40	CBM	PC	.750	.973	<.001

Hills, 2005	126	CBM	PC	.790	1.071	<.001
Hamilton, 2001	66	CBM	PC	.500	.549	<.001
	66	MAZE	PC	.300	.310	.014
Miller, 2001	30	CBM	PC	.760	.996	<.001
Denton, Cianco, & Fletcher, 2006	182	ORF	PC	.800	1.099	<.001
Vadasay, Sanders, &	36	LNF	PC	.260	.266	.126
Petyon, 2006	36	PSF	PC	.290	.299	.086
	36	ORF	PC	.330	.343	.049
	21	ORF gr 1	PC	.720	.908	<.001

Chard et al., 2008	668	ORF	PC GR 1	.650	.775	<.001
	525	ORF	PC GR 2	.610	.709	<.001
	425	ORF	PC GR 3	.560	.633	<.001
Spear-Swerling, 2006	61	ORF	PC	.570	.648	<.001
McIntosh, Graves, & Gersten, 2007	59	ORF	PC	.730	.929	<.001

Table A3
Studies relating Short-Term Memory to Basic Reading Skills

Study	Sample Size	STM variable	Basic Reading Skills Variable	Correlation	Fisher's Z	p-Value
Harvey, Storey & Buker, 2002	81	CTOPP Phonological Memory	LWI	.650	.775	<.001
Raskind et al., 2000	102	Digit Span	WID	.400	.472	<.001
	102	Digit Span	WA	.380	.400	<.001
	102	Nonword Mem	WID	.330	.343	<.001
	102	Nonword Mem	WA	.360	.377	.001
Naglieri & Reardon, 1993	30	Successive Dis	WA	.382	.402	.037
	30	Successive Nondis	WA	.471	.511	.008
Nagleri & Rojhan, 2004	617	Successive (5-7)	LWI	.290	.299	<.001
	443	Successive (8-10)	LWI	.400	.424	<.001
	217	Successive(11-13)	LWI	.510	.563	<.001
	617	Successive (5-7)	WAT	.180	.182	<.001

	443	Successive (8-10)	WAT	.400	.424	<.001
	217	Successive(11-13)	WAT	.510	.563	<.001
Joseph, et al., 2003	174	Phono Mem	LWI	.440	.472	<.001
	174	Phono Mem	WAT	.440	.472	<.001
	174	Successive	LWI	.410	.436	<.001
	174	Successive	WAT	.410	.436	<.001
McGrew & Woodcock, 2001	1031	Gsm (6-8)	BRS	.500	.549	<.001
	1787	Gsm (9-13)	BRS	.480	.523	<.001
	1031	WM (6-8)	BRS	.560	.633	<.001
	1787	WM (9-13)	BRS	.490	.536	<.001
O'shaughnessy, 1997	15	DS-pre math	WID	-.100	-.010	.728
	15	DS-post math	WID	.060	.060	.835
	15	DS-pre PAT	WID	.530	.590	.041
	15	DS-post PAT	WID	.390	.412	.154
	15	DS-pre WAT	WID	-.070	-.070	.808

	15	DS-post WAT	WID	.070	.070	.808
	15	DS-pre math	WAT	.030	.030	.917
	15	DS-post math	WAT	.180	.182	.528
	15	DS-pre PAT	WAT	.130	.131	.651
	15	DS-post PAT	WAT	.390	.412	.154
	15	DS-pre WAT	WAT	-.010	-.010	.728
	15	DS-post PAT	WAT	-.080	-.080	.781
Bowey, Cain, & Ryan, 1992	36	DSB low perf	WAT	-.050	-.050	.788
	32	DSB norm perf	WAT	.320	.332	.057
	36	DSF low perf	WAT	-.050	-.050	.788
	36	DSF norm perf	WAT	.037	.388	.026
Georgiou, Das, & Haywood, 2008	50	SQWM	WID	.390	.412	.005
Zavertnik, 2007	47	Gsm	WID	.675	.820	<.001

Kibby, 1999	18	WM	Word read	.320	.332	.199
	18	WM	Nonword read	.520	.576	.026
Katzir et al., 2006	17	MFD dys	WID	.003	.003	.991
	17	MFD nondys	WID	.030	.030	.911
	17	MFD dys	WAT	.003	.003	.991
	17	MFD nondys	WAT	.500	.549	.040
Cutting & Denckla, 2001	79	MS	WID	.310	.321	.005
McGrew, Werder, &	304	Gsm age 6	BRS	.410	.436	<.001
Woodcock	308	Gsm age 9	BRS	.469	.509	<.001
	267	Gsm age 13	BRS	.443	.476	<.001

Table A4

Studies relating short-term memory to reading comprehension (using a cloze-based assessment)

Study	**Sample Size**	**STM variable**	**Reading comp variable**	**Correlation**	**Fisher's Z**	**p-Value**
Swanson & Jerman, 2006	84	ADI wav 1	PC	.520	.576	<.001
	49	ADI wav 3	PC	.291	.300	.042
	68	ADI wav 2	PC	.290	.299	.016
	68	Rhym (2)	PC	.240	.245	.048
	84	Rhym(1)	PC	.410	.436	<.001
	49	Rhym(3)	PC	.060	.060	.684
	84	Update(1)	PC	.530	.590	<.001
	49	Update(3)	PC	.250	.255	.083
	68	Update(2)	PC	.430	.460	<.001
	84	WS (1)	PC	.460	.497	<.001

	68	WS(2)	PC	.340	.354	.004
Raskind Et al., 2000	102	DS	PC	.380	.400	<.001
	102	Nonwrd mem	PC	.300	.310	.002
Naglieri & Rojahn, 2004	217	Suc (11-13)	PC	.450	.485	<.001
	617	Suc(5-7)	PC	.210	.213	<.001
	443	Suc(8-10)	PC	.430	.460	<.001
McGrew & Woodcock,	799	Gsm 6-8	RC	.470	.510	<.001
2001	1489	Gsm 9-13	RC	.450	.485	<.001
	799	WM 6-8	RC	.530	.590	<.001
	1489	WM 9-13	RC	.490	.536	<.001
McGrew, Werder, &	267	Gsm 13	RC	.413	.439	<.001

Woodcock, 1991	301	Gsm 6	RC	.396	.419	<.001
	307	Gsm 9	RC	.548	.616	<.001
Swanson & Howell, 2001	100	Verb STM	RC	.250	.255	.012
	100	Vis STM	RC	.220	.224	.028
	100	Vis WM	RC	.190	.192	.038
O'Shaughnessy, 1997	15	DS-pre math	PC	.330	.343	.235
	15	DS-post math	PC	.290	.299	.201
	15	DS pre PAT	PC	.350	.365	.206
	15	DS post PAT	PC	.620	.725	.012
	15	DS pre WAT	PC	.100	.100	.728
	15	DS post WAT	PC	.030	.030	.917

Georgiou, Das, & Hayward, 2008	50	SQWM	PC	.400	.424	.004
Katzir et al., 2006	17	Mem dig dys	PC	.020	.020	.940
	17	Mem dig nondys	PC	.400	.424	.113

Table A5

Studies relating the relationship of processing speed to basic reading skills

Study	Sample Size	PS variable	BRS Variable	Correlation	Fisher's Z	p-Value
Havey, Story, & Buker (2002)	81	Rapid Naming	LWI	.490	.536	<.001
Georgiou, Parrika, & Stephenson (2008)	53	RAN L (2)	WID (2)	.290	.299	.035
	48	RAN-C (3)	WAT (3)	.140	.141	.344
	48	RAN-C (3)	WID (3)	.210	.213	.153
	53	RAN-C (1)	WAT (2)	.160	.161	.254
	53	RAN-C (1)	WID (2)	.270	.277	.050
	53	RAN-C(2)	WAT (2)	.110	.110	.435
	48	RAN-C(2)	WID (3)	.090	.090	.545
	53	RAN-C(2)	WID (2)	.180	.182	.198
	48	RAN-C(2)	WAT (3)	.090	.090	.545

53	RAN-D(1)	WAT (2)	.230	.234	.098
48	RAN-D(1)	WAT (3)	.060	.060	.687
53	RAN-D(1)	WID (2)	.390	.412	.004
48	RAN-D(1)	WID (3)	.230	.234	.116
53	RAN-D(2)	WAT (2)	.270	.277	.050
48	RAN-D(2)	WAT (3)	.180	.182	.222
53	RAN-D(2)	WID (2)	.400	.424	.003
48	RAN-D(2)	WID (3)	.360	.377	.011
48	RAN-D(3)	WAT (3)	.110	.110	.459
48	RAN-D(3)	WID (3)	.210	.213	.153
48	RAN-L(1)	WAT (3)	.380	.288	.007
53	RAN-L(1)	WAT (2)	.360	.377	.008
53	RAN-L(1)	WID (2)	.470	.510	.000
48	RAN-L(1)	WID (3)	.350	.365	.014
53	RAN-L(2)	WAT (2)	.130	.131	.355
48	RAN-L(2)	WAT (3)	.060	.060	.687

	48	RAN-L(2)	WID (3)	.320	.332	.026
	48	RAN-L(3)	WAT (3)	.040	.040	.788
	48	RAN-L(3)	WID (3)	.140	.141	.344
Raskind et al., 2000	102	RAN letters	WAT	.350	.365	<.001
	102	RAN letters	WID	.370	.388	<.001
	102	RAN both	WAT	.280	.288	.004
	102	RAN both	WID	.430	.460	<.001
	102	RAN numbers	WAT	.370	.388	<.001
	102	RAN numbers	WID	.400	.424	<.001
Compton, 2003	383	RANDR Fall	WID	.640	.758	<.001
	383	RANDR Spring	WID	.610	.709	<.001
	383	RANR Fall	WID	.640	.758	<.001
	383	RAN R Spring	WID	.620	.725	<.001

	383	RANV Fall	WID	.590	.678	<.001
	383	RANV Spring	WID	.540	.604	<.001
	383	RANVR Fall	WID	.660	.793	<.001
	383	RANVR Spring	WID	.600	.693	<.001
Joseph, McCachran, &	62	CTOPP RAN	LWI	.500	.549	<.001
Naglieri, 2003	62	CTOPP RAN	WAT	.330	.343	.008
Mariko-Doi, 1996	81	RAN digits	WID	.560	.633	<.001
	81	RAN digits	WAT	.480	.523	<.001
	81	RAN-5 letters	WID	.490	.536	<.001
	81	RAN-5 letters	WAT	.700	.867	<.001
	81	RAN-10 lttrs	WID	.580	.662	<.001
	81	RAN-10 lttrs	WAT	.630	.741	<.001
	81	RAN-25 lttrs	WID	.640	.758	<.001
	81	RAN-25 lttrs	WAT	.560	.633	<.001
	81	RAN picts	WID	.170	.172	<.001

	81	RAN picts	WAT	.290	.299	.129
Savage, Pillay, & Melidona	65	RAN colors	WAT	.150	.150	.234
(2008)	65	RAN digits	WAT	.500	.549	<.001
	65	RAN letters	WAT	.550	.618	<.001
	65	RAN objects	WAT	.120	.121	.342
Torgeson, et al., 1997	215	RLN (2)	WAT	.490	.536	<.001
	201	RLN (3)	WAT	.430	.460	<.001
	215	RLN (4)	WAT	.500	.549	<.001
	201	RLN (5)	WAT	.410	.436	<.001
	215	RLN (2)	WID	.650	.775	<.001
	201	RLN (3)	WID	.520	.576	<.001
	215	RLN (4)	WID	.590	.678	<.001
	201	RLN (5)	WID	.480	.523	<.001
	215	RNN (2)	WAT	.430	.460	<.001

	201	RNN (3)	WAT	.400	.424	<.001
	215	RNN (4)	WAT	.410	.436	<.001
	201	RNN (5)	WAT	.390	.412	<.001
	215	RNN (2)	WID	.570	.648	<.001
	201	RNN (3)	WID	.500	.549	<.001
	215	RNN (4)	WID	.480	.523	<.001
	201	RNN (5)	WID	.450	.485	<.001
McBride-Chang & Kail	109	Cross Out	WID	.450	.485	<.001
(2002)	109	Visual Matching	WID	.570	.648	<.001
Urso (2008)	44	Cross Out	BRS	.400	.424	.007
	44	D. Speed	BRS	.278	.286	.068
	44	Gs	BRS	.403	.427	.006
	44	Pair Canc	BRS	.488	.533	.001
	44	RPN	BRS	.338	.352	.024
	44	Visual Match	BRS	.462	.500	.001

Mcgrew & Woodcock	1031	Gs (6-8)	BRS	.500	.549	<.001
(2001)	1787	Gs (9-13)	BRS	.370	.388	<.001
McGrew, Werder, &	304	Gs (age 6)	BRS	.531	.592	<.001
Woodcock, 1991	308	Gs (age 9)	BRS	.490	.536	<.001
Bowey, McGuigan, &	28	Alphanumeric	Word reading	.480	.523	.009
Ruschena (2005)	28	Artic. Rate	Word reading	.400	.424	.034
	28	Glob Proc Spd	Word reading	.400	.424	.034
	28	Non-Symbol	Word reading	.310	.321	.109
Nehaus et al., 2006	120	RAN letter	WID	.280	.288	.002
	120	RAN letter	WAT	.270	.277	.003
Cutting & Denckla, 2001	79	Gs	WID	.420	.448	<.001
	79	RAN	WID	.560	.633	<.001
Nehaus, Foorman, Francis	25	LAT (1)	BS-17	.210	.213	.317
& Carlson (2001)	25	LPT (1)	BS-17	.660	.793	<.001

25	NAT (1)	BS-17	.270	.277	.194
25	NPT (1)	BS-17	.320	.332	.120
25	OAT (1)	BS-17	.270	.277	.194
25	OPT (1)	BS-17	.220	.224	.294
25	LAT (1)	BS-5	.010	.010	.963
25	LAT (2)	BS-5	.210	.213	.317
25	LPT (1)	BS-5	.840	1.221	<.001
25	LPT (2)	BS-5	.460	.497	.020
25	NAT (1)	BS-5	.180	.182	.393
25	NAT (2)	BS-5	.410	.436	.041
25	NPT (1)	BS-5	.570	.648	.002
25	NPT (2)	BS-5	.430	.460	.031
25	OAT (1)	BS-5	.220	.224	.294
25	OAT (2)	BS-5	.360	.377	.077
25	OPT (1)	BS-5	.280	.288	.177
25	OPT (2)	BS-5	.310	.321	.133

Bowey, Storey, &	125	An. Nam spd	WAT	.150	.151	.095
Ferguson, 2004	125	Clr Nam spd	WAT	.230	.234	.010
	125	Digit Nam spd	WAT	.210	.213	.019
	125	Lettr Nam spd	WAT	.400	.424	<.001
	125	Visual Match	WAT	.240	.245	.007
	125	ANS	WID	.160	.161	.075
	125	CNS	WID	.260	.266	.003
	125	DNS	WID	.340	.356	<.001
	125	LNS	WID	.430	.460	<.001
	125	VM	WID	.230	.234	.010

Table A6

Studies relating processing speed to reading comprehension (using a cloze-based assessment)

Study	Sample Size	PS variable	RC Variable	Correlation	Fisher's Z	p-Value
Raskind et al., 2000	102	RAN letters	PC	.440	.472	<.001
	102	RAN numbers	PC	.440	.472	<.001
	102	RAN numbers & letters	PC	.470	.510	<.001
Torgeson et al., 1997	216	RNN (2)	PC	.580	.662	<.001
	216	RLN (2)	PC	.660	.793	<.001
	216	RNN (4)	PC	.440	.472	<.001
	216	RLN (4)	PC	.550	.618	<.001
	201	RNN (3)	PC	.470	.510	<.001
	201	RLN (3)	PC	.520	.576	<.001
	201	RNN (5)	PC	.330	.343	<.001
	201	RLN (5)	PC	.440	.472	<.001

McGrew & Woodcock,	799	Gs (6-8)	RC	.480	.523	<.001
2001	1489	Gs (9-13)	RC	.380	.400	<.001
McGrew, Werder, &	301	Gs (age 6)	RC	.518	.574	<.001
Woodcock, 1991	307	Gs (age 9)	RC	.470	.510	<.001
Nehaus et al., 2001	25	LPT (1)	RC-5	.770	1.020	<.001
	25	LPT (1)	RC-17	.700	.867	<.001
	25	NPT (1)	RC-5	.440	.472	.027
	25	NPT (1)	RC-17	.380	.400	.061
	25	OPT (1)	RC-5	.320	.332	.120
	25	OPT (1)	RC-17	.280	.288	.177
	25	LAT (1)	RC-5	.060	.060	.778
	25	LAT (1)	RC-17	.240	.245	.251
	25	NAT (1)	RC-5	.180	.182	.393
	25	NAT (1)	RC-17	.130	.131	.540
	25	OAT (1)	RC-5	.120	.121	.572

	25	OAT (2)	RC-17	.270	.277	.194
	25	LPT (2)	RC-5	.580	.662	.002
	25	NPT (2)	RC-5	.280	.288	.177
	25	OPT (2)	RC-5	.220	.224	.294
	25	LAT (2)	RC-5	.160	.161	.449
	25	NAT (2)	RC-5	.200	.203	.342
	25	OAT (2)	RC-5	.360	.377	.077
Vadasy, Sanders, & Abbott,	79	RAN (1)	PC	.440	.234	<.001
2008	49	RAN (2)	PC	.230	.100	.112
	41	RAN (3)	PC	.100	.332	.536
Georgiou, Das, & Hayward,	50	RAN digits	PC	.320	.332	.023
2008	50	RAN letters	PC	.360	.377	.010