



12-2000

## **Cognitive processes as predictors of reading success**

Maripat Mullaly Gettelfinger

Follow this and additional works at: [https://trace.tennessee.edu/utk\\_graddiss](https://trace.tennessee.edu/utk_graddiss)

---

### **Recommended Citation**

Gettelfinger, Maripat Mullaly, "Cognitive processes as predictors of reading success. " PhD diss., University of Tennessee, 2000.  
[https://trace.tennessee.edu/utk\\_graddiss/8283](https://trace.tennessee.edu/utk_graddiss/8283)

This Dissertation is brought to you for free and open access by the Graduate School at TRACE: Tennessee Research and Creative Exchange. It has been accepted for inclusion in Doctoral Dissertations by an authorized administrator of TRACE: Tennessee Research and Creative Exchange. For more information, please contact [trace@utk.edu](mailto:trace@utk.edu).

To the Graduate Council:

I am submitting herewith a dissertation written by Maripat Mullaly Gettelfinger entitled "Cognitive processes as predictors of reading success." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Education.

Steve McCallum, Major Professor

We have read this dissertation and recommend its acceptance:

Donald J. Dickson, Sherry Bell

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a dissertation written by Maripat Mullaly Gettelfinger entitled "Cognitive Processes as Predictors of Reading Success." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Education.



R. Steve McCallum, Major Professor

We have read this dissertation  
and recommend its acceptance:



Accepted for the Council:



Interim Vice Provost and  
Dean of the Graduate School

**COGNITIVE PROCESSES AS PREDICTORS OF READING SUCCESS**

A Dissertation  
Presented for the  
Doctor of Philosophy Degree  
The University of Tennessee

Maripat Mullaly Gettelfinger  
December, 2000

## DEDICATION

This dissertation is dedicated to my family. To Buddy, thank you for your unconditional love, support, and understanding. But mostly, I thank you for always believing in me. To Andrew and Patrick, thank you for making sure I play a little everyday and for reminding me daily why children matter most.

To my parents, you instilled in me the work ethic and confidence that enabled me to achieve this accomplishment. Mom, I am so grateful for your tireless, loving care of my children and for being my pillar of strength. Dad, thank you for giving me the opportunities you never had and for instilling in me the importance of education. Susan, thank you for always being there to listen and make me laugh when you know I need to. I am especially grateful that you are so important in the lives of my children. Michael, you helped me discover a love of learning. I am so grateful for your unique insight and for your gift for writing that has assisted me through many papers throughout my educational experience.

You all continue to teach me life's most important lessons.

## ACKNOWLEDGMENTS

The faculty, staff, and students of Educational Psychology have been instrumental in making my experience in this program a very positive one. I am fortunate to have developed supportive and enduring relationships that I look forward to continuing throughout my career. I am especially grateful to my dissertation committee members for making this challenging yet fulfilling endeavor possible. I would like to express my gratitude to Steve McCallum, my committee chair, advisor, professor, and friend. Your help, patience, and support have been invaluable. To Donald Dickinson, you have been my advisor, professor, mentor, and friend from the beginning. Thank you for always being there to support me. To Sherry Bell, thank you for your knowledgeable and fresh perspective. To Richard Saudargas, thank you for thoughtful input and mostly, for guiding me in the direction of school psychology. I am very grateful to all of you for your guidance and assistance throughout my program of studies and the dissertation process.

### ABSTRACT

One hundred and five elementary and middle school students from a rural East Tennessee school district were evaluated using a new test of dyslexia, the Test of Dyslexia and Dysgraphia (TODD; McCallum & Bell, 1999). The TODD includes cognitive measures presumed to underlie reading. Also, reading achievement was assessed using the TODD, and for 73 of the students, by an end-of-year group administered test, the Terra Nova.

When cognitive variables were entered into Multiple Regression Analyses using reading achievement scores as criteria, Phonological Awareness was the strongest predictor of all criterion measures after extracting the variance accounted for by age. That is, phonological awareness predicted Letter-Word Calling, Decoding, Reading Comprehension, and Terra Nova Spelling and Reading Composite scores, with the range of variance accounting for from 76% to 21% for the criterion variables. Phonological awareness was the only significant predictor of Decoding and Terra Nova Reading Composite. However, when age was partialled out, the Reading Composite was significantly predicted by phonological awareness followed by visual processing which contributes an additional 4% of the variance, while Decoding was significantly predicted by phonological awareness followed by auditory memory which contributes an additional 1% of the variance. When age is not partialled out, phonological awareness accounted for 76% of the variance in Letter-Word Calling; rapid automatic naming accounted for an

additional 6% above that already accounted for by phonological awareness; visual processing accounted for an additional 2%, as did auditory processing; finally, auditory memory accounted for an additional 1%. When age is controlled for, phonological awareness accounted for 60% of the variance in Letter-Word Calling; Auditory processing accounted for an additional 1% of the variance; and visual memory accounted for less than 1% additional variance. When age is uncontrolled, phonological awareness accounts for 54% of the variance for Reading Comprehension and rapid automatic naming, visual processing and auditory memory account for 7%, 4%, 1% and 1% additional variance, respectively. When controlling for age, phonological awareness accounts for 19% of the variance for Reading Comprehension, and auditory processing and visual memory each predict an additional 1% of the variance, respectively. After phonological awareness, the next significant predictor of Terra Nova Spelling was auditory processing accounting for an additional 3% of the variance when age was not partialled out. When controlling for age, phonological awareness, auditory processing and visual memory predicted Spelling accounting for 20%, 6%, and 3% of additional variance, respectively.

These results are commensurate with current research emphasizing the predominance of phonological awareness and support the relative importance of rapid automatic naming, auditory memory and processing, and visual memory and processing in explaining the acquisition of beginning reading. Teachers of reading will find these results useful in understanding and designing curricula to develop the basic building



blocks of reading. Assuming data continue to support the development of the TODD, school psychologists will benefit from having one test available to diagnose dyslexia, rather than having to choose various subtests taken from a variety of instruments.

**TABLE OF CONTENTS**

1. INTRODUCTION.....1  
Background Information.....1  
The Development of a Working Definition of Dyslexia.....2  
Biological Evidence.....7  
Underlying Processes..... 8  
2. STATEMENT OF THE PROBLEM.....18  
3. RESEARCH QUESTIONS.....21  
4. METHODS.....22  
Participants..... 22  
Instruments..... 22  
Procedures.....26  
5. RESULTS.....28  
Research Question 1.....29  
Research Question 2.....30  
Research Questions 3 and 4..... 31  
6. DISCUSSION.....32  
Implications..... 47  
Limitations.....49  
REFERENCES..... 50

APPENDICES.....57  
VITA.....70

## APPENDICES

Table 1. Means and Standard Deviations of Cognitive and Reading Variables.....	58
Table 2. Intercorrelations of Cognitive Reading Subtests and Dependent Variables.....	59
Table 3. Multiple Regression Analyses Predicting Basic Letter-Word Calling from Cognitive Variables .....	60
Table 4. Multiple Regression Analysis Predicting Basic Letter-Word Calling from Cognitive Variables after Controlling for Age .....	61
Table 5. Multiple Regression Analysis Predicting Decoding from Cognitive Variables.....	62
Table 6. Multiple Regression Analysis Predicting Decoding from Cognitive Variables after Controlling for Age.....	63
Table 7. Multiple Regression Analysis Predicting Reading Comprehension from Cognitive Variable.....	64
Table 8. Multiple Regression Analyses Predicting Reading Comprehension from Cognitive Variables after Controlling for Age.....	65
Table 9. Multiple Regression Analysis Predicting Terra Nova Spelling from Cognitive Variables.....	66
Table 10. Multiple Regression Analyses Predicting Terra Nova Spelling from Cognitive Variables after Controlling for Age.....	67

Table 11. Multiple Regression Analysis Predicting Terra Nova Reading Composite from Cognitive Variables.....68

Table 12. Multiple Regression Analyses Predicting Terra Nova Reading Composite from Cognitive Variables after Controlling for Age.....69

## 1. Introduction

The purpose of this study was twofold. The primary purpose of this study was to determine the relative importance of cognitive abilities presumed to underlie the reading process using a new test of reading, the Test of Dyslexia and Dysgraphia (TODD) (McCallum & Bell, 1999). The underlying processes indicated by recent research (and operationalized via the TODD) to be fundamental to reading are phonological awareness, rapid automatic naming or processing speed, auditory short-term memory, auditory processing, visual memory, and visual processing. Scores from subtests assessing these processes were used to predict word calling, phonetic decoding and comprehension as measured by the TODD. The second purpose was to examine how well the aforementioned underlying processes predict end-of-year reading achievement scores as measured by the group achievement test used by the Tennessee State Department of Education, the Terra Nova.

### Background Information

Reading success is critical to overall academic success and is the single most important skill elementary students acquire. However, reading is a very complex endeavor and many students experience difficulty. In fact, according to the results of the 1999 Tennessee Comprehensive Assessment Program, only 64 percent of second graders in the state were reading at grade level and 70 percent of fifth-graders were “below

gifted” (Keim, 2000). According to Lyon (1995) and Shaywitz (1998), reading disabilities constitute the most prevalent type of learning disability (LD), affecting over 80% of the LD population. Experts seek to understand reading success by studying those cognitive processes assumed to underlie reading success and reading failure. In fact, the study of reading problems contributes significantly to understanding the acquisition of reading skills. Because dyslexia is assumed by many experts to be the most common reading disorder, affecting from around 3% to 30 percent of the population (Spafford & Grosser, 1996; Shaywitz, 1998; & Pennington, 1991), researchers spend considerable time and energy studying it. However, the study of reading problems lacks a cohesive framework from which to operate. For example, some experts use the term dyslexia interchangeably with reading disability, severe reading disability, severe reading disorder, specific reading disability and remedial reader (Spafford & Grosser, 1996). In addition, particular constructs believed to contribute to these difficulties are often described with differing terms by researchers. That is, the terms phonemic awareness, phonological processing, phonological analysis, and phonological sensitivity have been used interchangeably to refer to the same set of skills (Cronin & Carver, 1998), though not consistently. Furthermore, these skills and subskills are often assessed using different measures, introducing another confounding variable.

The Development of a Working Definition of Dyslexia

There is no singular definition of dyslexia in the field to guide research and the development of criteria for diagnosis and treatment (Vellutino & Scanlon, 1987).

Without a precise definition of the problem to be identified, assessment will more likely result in identification of a variety of reading disabilities as opposed to one specific disability. Therefore, children's specific reading disability may be misidentified and treatment may not necessarily match the needs of the student (Padget, Knight, and Sawyer, 1996).

According to Lyon (1995), a working operational definition of dyslexia is critically needed for identification, intervention and research purposes. He proposes that a valid definition of dyslexia should be developed with the following criteria as guidelines: 1) the definition must be theoretically based and informative as to skills necessary for reading skill and sources of difficulty for unskilled readers, 2) it should be supported by research and clinical information, 3) the supporting research should be based on studies with well described samples of subjects (to reduce confounding variables), 4) it should be based on inclusionary descriptions of dyslexia in terms of constructs that can be measured directly, and 5) it should be externally valid in terms of providing clear criteria for assessment and instruction. However, many current definitions are exclusionary, contain vague criteria, or are based on research evidence based on poorly defined samples.



Exclusionary definitions define dyslexia by what it is not, offering no clear conceptualization by which to distinguish children with dyslexia apart from poor readers (those with unspecified reading disabilities) (Catts, 1991). Pennington's (1991) definition of dyslexia is an example of an exclusionary definition: "an unexpected difficulty in learning to read and spell. Unexpected means that there is no obvious reason for the difficulty, such as inadequate schooling, peripheral sensory handicap, acquired brain damage, or low overall IQ" (pp. 45-46). Exclusionary models oblige clinicians to diagnose dyslexia by ruling out other possible neurological or cognitive deficits. This method is inefficient for both identification and treatment purposes.

Many definitions of dyslexia contain terminology that is vague and difficult to operationalize (Lyon, 1995). For example, Critchley defines dyslexia as "a disorder manifested by difficulty in learning to read despite conventional instruction, adequate intelligence, and sociocultural opportunity. It is dependent upon fundamental cognitive disabilities which are frequently of constitutional origins"(as cited by Spafford & Grosser, 1996, p.33). This definition published in 1970 is still accepted by the World Federation of Neurology (Spafford & Grosser, 1996). Critchley's broad definition relies upon exclusionary criteria that are often difficult to operationalize (e.g., "conventional instruction," "sociocultural opportunity") and therefore measure, making it difficult to replicate research findings (Lyon, 1995; Martin, 1995). In addition, Pennington's and Critchley's definitions both suggest that the criteria for diagnosis rely on a discrepancy

between IQ and reading achievement, a procedure that is being called into question in light of recent research (Lyon, 1995).

Studies have shown that little difference exists between discrepant poor readers (reading disabled children with high IQs) and reading disabled students with commensurate IQ-reading score (nondiscrepant poor readers) on measures of skills considered essential for reading (Lyon, 1995). For example, Shaywitz, Fletcher, Holahan, & Shaywitz (1992) assessed discrepant and nondiscrepant poor readers on measures of visual perception, manual dexterity, linguistic function and teacher's assessment of learning and behavior and found insignificant differences. Similarly, Fletcher, Shaywitz, Shankweiler, Katz, Liberman, Steubing, Francis, Fowler, & Shaywitz (1994) compared discrepant and non-discrepant poor readers on 9 cognitive variables related to reading proficiency. The groups differed little on most measures, and particularly on those measures of phonological awareness, which are the most robust indicators of differences between reading disabled children and non-impaired readers, regardless of how reading disability is defined (Lyon, 1995).

Some questions have been raised about the appropriateness of using group data given the heterogeneity of deficits among dyslexics. It is generally accepted that dyslexics have varying profiles with different strengths and weakness and that these profiles may change with age (Blachman, 1983; Cronin and Carver, 1998). In fact, the discovery of subgroups within the population of dyslexics with similar profiles has prompted a surge of research on dyslexic subtypes (Roberts and Mather, 1997). When

there is a significant difference between impaired groups and control groups, it is often erroneously assumed that the finding generalizes to the whole group (Martin, 1995). These issues have probably contributed to the failure of some studies to be replicated and have contributed to the continuing debate over the underlying cause or causes of dyslexia.

Even though there is controversy over the cause or causes of dyslexia (Vellutino, 1987), several definitions reflect some of the most common themes found in the current literature on dyslexia while meeting the criteria for valid working definitions as set forth by Lyon (1995). For example, the following definition, developed by the Orton Dyslexia Society, was recently adopted by the National Institutes of Health:

Dyslexia is one of several distinct learning disabilities. It is a specific language-based disorder of *constitutional origin* characterized by difficulties in single word *decoding*, usually reflecting *insufficient phonological processing abilities*. These difficulties in single word decoding are often unexpected in relation to age and other cognitive and academic abilities; they are not the result of generalized developmental disability or sensory impairment. Dyslexia is manifest by variable difficulty with different forms of language, often including, in addition to problems in *reading*, a conspicuous problem with acquiring proficiency in *writing* and *spelling*. (Greene, 1996; Lyon, 1995) [italics added]

The following definition was created to guide the work of the Tennessee Center for the Study and Treatment of Dyslexia and is adopted by this author for the purposes of this study:

Dyslexia is a language-based learning disorder that is *biological in origin* and primarily interferes with the acquisition of print literacy (*reading, writing, and spelling*). Dyslexia is characterized by poor *decoding* and spelling abilities as well as *deficits in phonological awareness and/or phonological manipulation*. These primary characteristics may co-occur with spoken language difficulties and deficits in short-term memory. Secondary characteristics may include poor reading comprehension (due to the decoding and memory difficulties) and poor written expression, as well as difficulty organizing information for study and retrieval.” (Padget et al. 1996, p. 55) [italics added]

Contained in these two definitions are the most agreed upon premises in the body of research on dyslexia. It is now widely accepted that dyslexia has biological origins, and is characterized by deficits in decoding and phonological awareness that are manifested in difficulties in reading, writing and spelling.

### Biological Evidence

The emergence of recent neuroimaging techniques and genetic studies provides evidence that dyslexia is biological, heritable and familial. The use of the functional magnetic resonance imaging (fMRI) to examine blood flow in the brain during a reading task has shown differential patterns in dyslexics and nondyslexics. Shaywitz (1998) and colleagues at the Yale Center for the Study of Learning and Attention have identified areas of the brain that are activated in speech production. Their results showed increased activity in this part of the brains of dyslexics. They hypothesize that dyslexics may be

trying to find another way to decode a word due to inefficient pathways (Kantrowitz & Underwood, 1999).

Another interesting outcome of fMRI studies is the discovery of genetic difference in the brains of dyslexics. Contrary to previous belief, similar numbers of boys and girls are affected with dyslexia. However, fMRI studies on the brains of dyslexics when performing a phonological task reveals that the left frontal gyrus is activated in males, whereas both the left and right inferior frontal gyrus is engaged in females (Shaywitz, 1996). This bilateral representation of the brains of women may explain why dyslexic women tend to compensate better than dyslexic men with their dyslexia (Shaywitz, 1996). This difference in the ability to compensate may also be implicated in the higher number of males being identified more often.

According to Shaywitz (1998), family history is one of the most important risk factors. It has been estimated that from 23 to 65 percent of children with dyslexia have a parent that has been identified as dyslexic. Furthermore, recent genetic linkage analyses suggest autosomal dominant transmission (Lyon, 1995).

### Underlying Processes

The literature on phonological processing is perhaps the most prolific in the field of dyslexia. Lyon conceptualizes (1995) phonological processing as comprised of three components: Phonological awareness; phonological recoding in lexical access; and phonetic recoding in working memory (Wagner and Torgeson, 1987). Phonological awareness refers to the ability to recognize the parts, patterns and structures of language

(Rooney, 1995). In order to be able to recognize these relationships, a child must understand the sound/symbol correspondences between 44 phonemes (the smallest unit of sound in the English language) and letters or combinations of letters (Spafford & Grosser, 1996). Slow and inaccurate word attack (decoding) and word recognition result when there is a compromised awareness of the speech-sound constituents of words and the ability to associate them with symbols (Adams & Bruck 1995; Beck & Juel 1995; Liberman & Shankweiler 1979; Lyon, 1995). Word calling of isolated words and/or pseudowords (or nonsense words) should be especially difficult for children with dyslexia as it is a decoding (i.e., sounding out phonemes to correctly identify words) specific task with no contextual cues. In the absence of context, whole-word substitutions are often made more frequently than incorrect attempts at “sounding out” (Padget et al., 1996).

As previously mentioned, spelling is closely related to word-calling, and phonological awareness, as it represents the phonological code in reverse. In other words, word-calling corresponds to the ability to “move from letters to phonological representations” and spelling reveals the ability to “move from phonological representations to letters” (Oakland, Black, Stanford, Nussbaum, & Balise, 1998, p. 146). According to Padget et al. (1996), spelling skill is superior to word recognition skill for identification purposes because it presents a clearer picture of grapheme-phoneme relationship and the child’s ability to manipulate them when learning new words.

According to the literature, deficits in phonological awareness are causally related to reading impairment and are the best predictors of dyslexia (Catts 1986; Gough & Tunmer 1986; Kahmi, Catts, and Mauer 1990; Liberman & Shankweiler 1979; Lundborg, Oloffson, & Wall 1980; Lyon 1995; Spafford & Grosser, 1996; Wagner & Torgesen 1987). According to Cronin and Carver (1998), phonological awareness is best assessed by rhyme discrimination for younger children and phoneme deletion and segmentation tasks for older children.

Phonological recoding in lexical access is typically assessed by tasks requiring rapid retrieval of colors, objects or letters and is considered to reflect the process of automatization (Lyon, 1995). Thus, phonological recoding may be directly dependent upon speed. According to Cronin and Carver (1998), "children with severe reading problems have difficulty with more general automatic responses, such as naming the days of the week and the months of the year or reciting multiplication tables." Increasingly, evidence shows that rapid naming, along with measures of phonological processes, are the best predictors (or predict significant variance) of reading achievement. For example, Felton (1992) found that a task of speed of naming letters and two measures of phonological awareness correctly identified 89% of superior readers and all the poor readers in the study (when controlling for IQ).

Rapid naming has been shown to predict word calling better than comprehension. Therefore, rapid naming seems to be more related to orthographic skill and automaticity than to other reading components (Cronin & Carver, 1998). Wolf (1999) found that

children generally fall into four subgroups of reading ability. The first group is composed of average readers with no deficits. The second is composed of children with intact decoding skills but have naming speed deficits. The third group is composed of children with phonological awareness deficits who have poor decoding but adequate naming speed skills. The second and third groups have moderate comprehension deficits. However, children in the fourth group have “both naming-speed and phonological awareness problems and pervasive problems in word attack, word identification, and comprehension” (Wolf, 1999, p.13). This so-called “double deficit” subtype is the most seriously impaired as they have no compensatory route to reading and as such, are the most at risk for dyslexia.

Based on recent research, Wolf has hypothesized that naming speed may be an index of dysfunction in lower-level processes that contribute to a rate of processing problem that may affect various aspects of reading. This line of research has contributed to the debate over what rapid automatic naming (RAN) measures. Studies investigating the relationship of RAN to other predictors of reading, indicate that processing speed has an impact on RAN but also impacts phonological awareness and memory (Denckla & Cutting, 1999). Therefore, while RAN is mostly accounted for by processing speed, it does not uniquely measure processing speed as there is significant overlap with phonological awareness and memory. Therefore, phonological awareness, rapid naming and rote memorization are essential elements of the definition of dyslexia, thus, these elements need to be assessed as part of developing a diagnosis.



Operationalization of phonetic recoding (i.e., phonemic manipulation) in working memory may occur using digit span, word and sentence span tasks and thus, reflects a strong short-term memory component (Shaywitz, 1996). Dyslexics have been shown to have inefficient short-term and long-term memories, which affects “phonological encoding of information, the use of rehearsal strategies and retrieval cues, and organizational and evaluative strategies” (Spafford & Grosser, 1996). Auditory short-term memory is evidenced by difficulty in recalling isolated words, letters or numbers sequentially. Dyslexics’ difficulty processing information aurally is believed to be related to underlying difficulty processing syntactically complex language. When trying to retrieve information rapidly, related phonemes or incorrectly ordered phonemes are often recalled (Shaywitz, 1996). Thus tasks such as spelling and recalling telephone numbers are especially problematic for dyslexics. Measures of auditory closure (tasks such as identifying an incomplete word presented orally) and auditory memory (such as word memory or digit span tasks) can assist in arriving at a diagnosis (Greene, 1996).

There is growing evidence that the assessment of listening comprehension is essential in the diagnoses of dyslexia. Hoover and Gough (1990) found that by measuring decoding and listening comprehension and multiplying these measures, one can almost perfectly predict how well children read (Gough, 1996). In addition, “there is increasing evidence that listening comprehension scores are a better predictor of reading achievement and that the relationships among oral and written language skills contributes more to understanding reading problems than the discrepancy between IQ and reading

achievement” (Padget et al., 1996, p. 59). However, listening comprehension is not often included in assessment batteries when investigating IQ-achievement discrepancy.

Recent scientific research has eradicated the once widely held belief that dyslexia is a visual perceptual deficit. Instead, dyslexics “usually perform quite normally on visual-spatial tasks while demonstrating severe deficits in tasks of auditory or visual temporal processing, motor sequencing, phonological processing and memory, language, reading, and spelling” (Tallal & Fitch, 1993, pp.168-69). Visual sequential memory problems are common among dyslexics as evidenced by their difficulty with sequential recalling of letters, words and numbers. However, recall for objects or designs is usually at least average and visual-spatial-motor integration is often a talent among dyslexics with no other co-morbid diagnoses (Greene, 1996).

Automatic, fluent reading cannot be achieved without mastery of the crucial components of reading. Reading comprehension will be seriously compromised when so much cognitive effort is put into decoding individual words (Rooney, 1995). The degree to which reading comprehension is affected will depend on the dyslexics’ ability to use context to achieve word recognition. Dyslexics will typically have better listening comprehension scores than reading comprehension but the level of discrepancy will depend on the individual’s word identification skills (Vellutino, Scanlon, & Tanzman, 1994). In other words, dyslexic children with better developed word identification skills will have reading comprehension scores more in line with listening comprehension skills (Padget et al., 1996).

Padget's group suggests that dyslexics often exhibit the following profile:

listening comprehension is greater than reading comprehension; reading comprehension is greater or equal to word recognition; word recognition is greater than or equal to spelling; spelling is greater than or equal to decoding; decoding is greater than or equal to phonological awareness. Therefore, in most cases, listening comprehension should represent a strength, while phonological awareness should reveal a significant deficit since this skill is the core deficit area of dyslexia.

Scores for word recognition and reading comprehension subtests are usually used in the school setting to represent reading ability. However, a specific diagnosis of dyslexia cannot be made without measuring the other essential components of reading. Padget et al. (1996) assert that the performance on these criteria need to be considered independently and as they relate to one another.

Currently, there are measures of many of these constructs available, but not in one test designed solely to assess dyslexia, i.e., there is no single test of dyslexia. The best attempt to operationalize many of these underlying processes comes from Richard Woodcock and his colleagues (1989). The Woodcock-Johnson Psycho-Educational Battery-Revised (WJ-R), contains measures of a number of cognitive abilities presumed to most strongly underlie reading; several of these comprise the Reading Aptitude Cluster as identified by the WJ-R authors:

1. Memory for Sentences is a measure of short-term auditory memory and is assessed by the ability to remember and repeat single words, phrases and sentences (Mather, 1991, p.20).
2. Visual Matching is a measure of processing speed and is assessed by “the ability to locate and circle the two identical numbers in a row of six numbers” with an ascending order of difficulty with a time constraint of 3 minutes (Mather, 1991, p. 20).
3. Sound Blending is a measure of auditory processing and is assessed by the “ability to integrate and then say whole words after hearing parts (syllables and /or phonemes) of the words” (Mather, 1991, p.22).
4. Oral Vocabulary is a measure of word meanings using antonyms and synonyms. To measure Antonym knowledge, “the subject must state a word opposite in meaning to the word presented.” To measure synonyms, “the subject must state a word similar in meaning to the word presented” (Mather, 1991, p. 22).

These and other cognitive subtests are related to word recognition, decoding and comprehension, the principal components of reading. On the WJ-R, decoding is measured by Word Attack (applying phonic analysis to the pronunciation of nonsense words) and word recognition is measured by Letter-Word Identification (identifying symbols, letters, and words in isolation). The correlations between the WJ-R’s cognitive subtests thought to underlie reading, Memory for Sentences, Visual Matching, Sound

Blending, and Oral Vocabulary and Word Attack are .37, .36, .48, .47, respectively. The correlations between the aforementioned cognitive subtests and Letter-Word Identification are .46, .38, .43, .64, respectively.

The WJ-R subtests that measure reading comprehension are Passage Comprehension and Reading Vocabulary. Passage Comprehension involves identifying the correct missing key word in a reading passage, while Reading Vocabulary requires reading words and supplying an appropriate antonym or synonym. The correlations between Memory for Sentences, Visual Matching, Sound Blending, and Oral Vocabulary and Passage Comprehension are .45, .35, .43, .64, respectively. The correlations between these same cognitive subtests and Reading Vocabulary are .50, .35, .41, .76, respectively. Other measures are also related to reading, but not as strongly. For example, listening comprehension, written composition, visual processing, spelling, punctuation, capitalization and usage are considered important elements in a complete assessment of reading disorders. While the WJ-R offers these subtests in either the cognitive or achievement batteries, they are not contained in a single battery for the expressed purpose of identifying dyslexia.

A new test, the Test of Dyslexia and Dysgraphia (TODD) (McCallum & Bell, 1999), contains all the subtests generally considered necessary to make the diagnosis. Many of the TODD subtests are similar to several of the WJ-R subtests. For example, the subtest on the TODD that corresponds to the WJ-R's Memory of Sentences is Word Memory which also measures short-term auditory memory. Similar to Visual Matching

on the WJ-R, the TODD's Visual Processing Accuracy and Speed is measure of processing speed. Auditory processing is measured by Auditory Gestalt on the TODD, while WJ-R's auditory processing subtest is Sound Blending. Both Oral Vocabulary from the WJ-R and Vocabulary on the TODD measure word meaning and are also measures of general intelligence. Since factor analyses of the WJ-R found these subtests to best comprise the Reading Aptitude Cluster, the corresponding TODD subtests should hypothetically make-up a similar cluster. However, the TODD contains several measures assumed to be related to reading that are not offered on the WJ-R. These measures include an operationalization of processing speed (or rapid automatic naming) more ecologically related to reading (Rapid Symbol Naming) than the processing speed subtest of the WJ-R. In addition, the TODD includes a listening comprehension subtest, assessment of regular and irregular spelling words, and a unique measure of phonemic awareness, all operationalizations important to understanding reading but not found on the WJ-R.

## 2. Statement of the Problem

Currently, reading disabilities are usually diagnosed when a discrepancy between intelligence and reading achievement occurs. This method does not differentiate among types of specific reading disabilities, including dyslexia. With an unspecified diagnosis of reading disability, teachers may not have adequate information for the most appropriate and efficient intervention. Thus, it is important to obtain good operationalizations of the various cognitive and achievement based characteristics. Then it is important to understand how these elements are juxtaposed, leading to specific diagnoses.

Current diagnostic procedures usually require intelligence testing and a battery of reading tasks. While these results can be used to satisfy the IQ-achievement discrepancy for identification purposes, these methods often offer an inadequate profile of strengths and weaknesses with little treatment validity. In addition, according to the literature, the IQ-discrepancy formula is inappropriate for diagnostic and treatment purposes because knowledge of a discrepancy does not lead to an awareness of the cognitive constructs underlying reading disabilities, which is critical for accurate diagnosis and treatment. However, using currently available measures it is difficult to obtain the data needed to provide a comprehensive assessment of cognitive and achievement variables needed for a diagnosis', it is necessary for subtests to be taken from a variety of test batteries. These procedures can be cumbersome and results may be difficult to interpret (e.g., different standardization samples used in the development of different instruments are directly

compared even though the data from one test may be considerably older than data from another). In short, there is not one test available which provides measures of all of the constructs necessary to diagnose dyslexia based on current research.

The Test of Dyslexia and Dysgraphia (TODD) (McCallum & Bell, 1999) has both the intelligence component and reading achievement component necessary to meet state regulations for diagnosis of reading disabilities, and it includes measures of all the constructs needed for the specific diagnosis of dyslexia.

The TODD offers a battery of subtests designed to provide measures on the underlying processes considered essential to reading in one test. The TODD includes all the components necessary for diagnosing dyslexia based on the hierarchy of strengths and weaknesses considered typical for the profile of a dyslexic child (Padgett et al., 1996).

Using the TODD, it is possible to operationalize a dyslexia profile, as follows:

1. IQ, Visual Processing Accuracy (VPA) and Listening Comprehension (LC) equal to or greater than 85.
2. LC, IQ, VPA greater than Reading Comprehension (RC).
3. Letter/Word Calling (LWC) and Visual Processing Speed (VPS) equal to or less than RC and less than LC, IQ, and VPA.
4. Spelling equal to or lower than LWC and less than LC, IQ, and VPA.
5. LWC equal to or greater than Auditory Gestalt (AG), Phonological Awareness (PA) and/or Rapid Symbol Naming (RSN).
6. AG, VPS, Word Memory (WM), PA, and/or RSN below IQ.



The TODD provides operationalizations of the various components underlying reading. Thus, scores from the relevant subtests can be used in a predictive fashion to determine which of the cognitive elements are most critical. Scores from the WJ-R have been used in this fashion to some extent. However, there is a need to measure the relative predictive capability of these cognitive abilities independently of the WJ-R. In addition, there is a need to use a more inclusive set of predictor variables, i.e., all the major variables thought to underlie reading. In this study, the following variables will become predictors in a multiple regression format:

### 3. Research Questions

1. What is the relative capability of the various cognitive components: phonological awareness (Phonological Awareness), rapid automatic naming (Rapid Symbol Naming), auditory short-term memory (Word Memory), auditory processing (Auditory Gestalt), visual memory (Memory for Symbols) and visual processing (Visual Perceptual Speed and Accuracy) thought to underlie reading to predict basic reading skills (as measured by two criteria: Letter-Word Calling and Decoding), as measured by the TODD?
2. What is the relative capability of the various cognitive components thought to underlie reading to predict comprehension (Reading Comprehension), as measured by the TODD?
3. What is the relative capability of the various cognitive components thought to underlie reading to predict decoding (Spelling), as measured by the Terra Nova?
4. What is the relative capability of the various cognitive components thought to underlie reading to predict reading composite (Vocabulary and Reading Comprehension), as measured by the Terra Nova?

#### 4. Methods

##### Participants

Participants in this research study were 105 students from an elementary and middle school in a rural county in East Tennessee. The student population of the participating schools was predominately Caucasian, with 2% African American and less than 1% Hispanic Students. Participants were drawn from a school located in a somewhat economically depressed area. Fifty-one percent of the families of the population of the students are below the poverty level, as defined by eligibility for the federally funded free or reduced fee lunch program. Students from kindergarten through sixth grade were randomly selected to participate based on the return of signed permission slips. There were 50 males and 55 females in the study. Ages ranged from 5 through 12. Four children in the study were receiving special education services. However, 6 have been identified with speech and language problems, 9 as reading disabled, 3 as mathematics disabled, and 3 have written expression disabilities.

##### Instruments

The TODD is an individually administered test battery designed for children ages 5-12 to provide the information necessary for a diagnosis of dyslexia and dysgraphia. It was developed to assess dyslexia according to a formula developed by Padget, Knight, and Sawyer (1996) that provides measures necessary to identify a characteristic profile of children with dyslexia. They suggest a profile such that intelligence and listening

comprehension are approximately average (e.g., greater than 85 on a general IQ test), that reading comprehension and auditory processing are less than listening comprehension and IQ, that word recognition is equal to or less than reading comprehension and less than listening comprehension and IQ, that phonetic decoding is equal to or less than word recognition, and that phonemic awareness is well below age expectation. Also, in order to rule out reading problems due to the effects of visual- perceptual/processing problems, scores on a motor reduced test of visual perception should be obtained and should be in the average range.

The TODD is comprised of 14 individual subtests. Two subtests are used to yield an estimate of the examinee's general level of cognitive functioning. These two subtests are Vocabulary, which measures word knowledge, and Matrix Analogies which assesses a child's level of non-verbal reasoning. Split-half reliabilities were calculated and are .88 and .87, respectively.

Five of the subtests measures a child's achievement in areas associated with reading ability. They include: Letter-Word Calling, Decoding, Reading Comprehension, Spelling, and Listening Comprehension. Letter-Word Calling assesses letter and sight word recognition. Decoding measures the ability to decode nonsense words by their phonetic properties. Reading Comprehension measures the ability to comprehend written passages. Spelling assesses a child's ability to spell both phonetically regular and irregular words in isolation. Listening Comprehension assesses the ability to comprehend meaningful information presented orally. Reliability indices are .96, .96, .97 .92, and .92,

respectively. In addition, a dysgraphia measure, Written Composition, is included and assesses basic writing skills (e.g., punctuation, organization, fluency, and detail) and legibility (e.g., spacing, letter formation and size, and pencil pressure and grip).

Certain subtests are presumed to assess underlying cognitive abilities. These include: Phonological Awareness which measures the ability to manipulate phonemes in phonetically regular pseudowords, Word Memory which measures auditory memory, and Auditory Gestalt which measures auditory processing and is divided into two parts measuring the ability to accurately process incomplete words (Closure) and synthesize phonetically divided words presented orally (Synthesis). Reliabilities for these subtests are .91, .70, .80, and .80, respectively. Rapid Symbol Naming, a measure of rapid automatic naming, assesses the processing speed and accuracy with which children can call letters and numbers. Reliability measures are not appropriate for Rapid Symbol Naming as it is a continuous rather than discrete trial task.

Visual processing and processing speed are measured by Visual Perceptual Accuracy and Speed. Visual Perceptual Accuracy and Speed is divided into two parts. Visual Perceptual Accuracy and Speed 1 (Discrimination) measures the ability to visually discriminate similar stimuli accurately under time constraints. Visual Perceptual Accuracy and Speed 2 (Closure), measures the ability to complete visually incomplete stimuli under time constraints. The speeded portion of these tasks measures processing speed in a manner similar to the Wechsler Intelligence Scale for Children III (WISC III) (Wechsler, 1991) and the Woodcock Johnson - Revised Tests of Cognitive Ability

(Woodcock & Mather, 1989). There is a visual memory (Memory for Symbols) subtest as well which measures a child's ability to remember a group of unrelated letters presented visually. Split-half reliability is .91 for Visual Perceptual Accuracy and Speed 1 (Discrimination), .91 for Visual Perceptual Accuracy and Speed 2 (Closure), and .86 for Memory for Symbols (visual memory).

The Terra Nova is a group administered achievement battery administered to children in Tennessee; it is designed to measure concepts, processes, and skills that reflect educational objectives found in state, district and national standards guidelines (Terra Nova Technical Bulletin, 1996). A portion of the Terra Nova consists of the nationally normed Comprehensive Tests of Basic Skills (CTBS-4) measures (1989). The criterion measures used in this study are taken from the CTBS-4. Since kindergarten and 1st grade students are not administered the Terra Nova, scores from a total of 73 students were obtained. The Terra Nova Reading Composite is comprised of two subtests, Reading Comprehension and Vocabulary. Comprehension items require the student to indicate the central meaning of a passage and progress from initial understanding to interpretation and evaluation. On the Vocabulary subtest students are required to select the most appropriate word to reflect the meaning of a passage. Measures of knowledge of synonyms, antonyms, and multi-meaning words are also contained in the Vocabulary subtest. Since the tasks included on the Vocabulary subtest are heavily reliant on comprehension and group administered achievement tests such as the Terra Nova do not lend themselves well to measures of decoding, the Spelling subtest is used as a criterion

of decoding as it is more closely related to word-calling and phonological awareness. Vocabulary and Reading Comprehension, which comprise the Reading Composite, will be used as the Comprehension criterion.

Coefficient alpha was used to determine internal consistency. The split-half coefficient correlation was adjusted using the Spearman-Brown formula. Reliabilities for Reading Comprehension range from .90 to .93 for grades two through six. Vocabulary reliabilities range from .82 to .87. The Reading Composite reliabilities range from .93 to .95. Spelling reliabilities range from .72 to .82

#### Procedures

Permission slips were provided to each student at an elementary and middle school in a rural county in East Tennessee. Students were randomly selected from those with signed permission. Selected students were informed as to the nature and approximate length of the TODD. The examiner explained that participation was voluntary and that the student could drop out of the study at anytime without penalty. Investigators or assistants tested each student individually. The test requires approximately one and one half hours and was administered during school hours at a time deemed most appropriate by the student's teacher. Testing was conducted on school grounds in classrooms and/or offices according to privacy and availability.

Test results are confidential and do not contain names or identifying information. Terra Nova scores for participating students were provided by school personnel. Testing materials were coded should parents or teachers request feedback on a particular student's

results. If requested, feedback was given in terms of strengths and weaknesses, and recommendations were provided.

TODD subtest scores for each student were calculated based on raw scores (number of items correct and completion times on speeded tasks). Terra Nova scores were in the form of National Curve Equivalents with a mean of 50 and standard deviation of 21.06. These scores were used to answer the following research questions:

1. What is the relative capability of the various cognitive components thought to underlie reading to predict word calling and decoding, as measured by the TODD?
2. What is the relative capability of the various cognitive components thought to underlie reading to predict comprehension, as measured by the TODD?
3. What is the relative capability of the various cognitive components thought to underlie reading to predict decoding (Spelling), as measured by the Terra Nova?
4. What is the relative capability of the various cognitive components thought to underlie reading to predict Reading Composite, as measured by the Terra Nova?

Because predictive and criterion variables were influenced by maturation and because standard scores were not yet available on the TODD, a second series of Multiple Regression Analyses were computed for all research questions with age partialled out. That is, age was forced into the equation as the first variable.



## 5. Results

Data necessary to address the research questions are shown in the Results section of this study. The first question addresses the relative capability of the following cognitive components to predict basic reading skills (as assessed by two dependent variables, Letter-Word Calling and Decoding from the TODD): phonological awareness (Phonological Awareness), rapid automatic naming (Rapid Symbol Naming), auditory short-term memory (Word Memory), auditory processing (Auditory Gestalt), visual memory (Memory for Symbols) and visual processing (Visual Perceptual Accuracy and Speed) as measured by the TODD. The second question investigates the capability of these same cognitive components to predict a third dependent variable, Reading Comprehension, as measured by the TODD. The third and fourth research questions focus on the capability of the cognitive components as operationalized by the TODD to predict decoding (Spelling) and reading (Reading Composite composed of the Vocabulary and Reading Comprehension subtests) as measured by the Terra Nova.

Raw scores were obtained on participants ranging in age from 5 to 12 years old. Descriptive statistics show means and standard deviations of cognitive and criterion variables (see Table 1; all tables are contained in the Appendices). A correlation matrix shows relationships among the cognitive and criterion (reading) variables (see Table 2). To determine the relative predictive ability of the cognitive components, step-wise Multiple Regression Analyses (MRA) were conducted according to two equations.

Multiple Regression Analyses were conducted with and without age entered as a predictor variable; age was entered first in each equation of the second set of regression analyses to account for the developmental influences inherent in the predictor variables.

Observation of the correlation matrix shows that all predictor and criterion variables are moderately to highly correlated, ranging from  $-.30$  to  $.91$ . In particular, correlations among cognitive predictor variables are significantly related, suggesting considerable overlap.

#### Research Question 1

Letter-Word Calling and Decoding from the TODD are the dependent variables examined in Question 1. Phonological Awareness accounted for 76% of the variance in Letter-Word Calling; Rapid Symbol Naming Ratio (derived by dividing accuracy by time completed) accounts for an additional 6% above that already accounted for by Phonological Awareness; Visual Perceptual Accuracy and Speed 2 (Closure) accounts for an additional 2%, as did Auditory Gestalt B (Synthesis); finally, Word Memory accounting for an additional 1% (see Table 3). Phonological Awareness explains 83% of the variance in Decoding and no other predictor variable contributes significantly. The relationships between predictor and criteria variables were also examined after controlling for age. Age accounts for 55% of the variance in Letter-Word Calling; Phonological Awareness accounts for an additional 32% of the variance; Auditory Gestalt B (Synthesis) accounts for an additional 1%; and Memory for Symbols accounts for less than 1% of the variance (see Table 4). Age accounts for 23% of the variance in

Decoding; Phonological Awareness accounts for an additional 60% of the variance and Word Memory accounts for less than 1% more. These results are shown in Tables 5 and 6.

### Research Question 2

The second research question addresses the relative capability of the following cognitive components to predict Reading Comprehension as measured by the TODD: phonological awareness (Phonological Awareness), rapid automatic naming (Rapid Symbol Naming), auditory short-term memory (Word Memory), auditory processing (Auditory Gestalt), visual memory (Memory for Symbols) and visual processing (Visual Perceptual Accuracy and Speed). Phonological Awareness, Rapid Symbol Naming, and Visual Perceptual Accuracy and Speed 1 (Discrimination), Visual Perceptual Accuracy and Speed 2 (Closure), and Word Memory are all significant predictors of Reading Comprehension. Phonological Awareness accounts for 54% of the variance, Rapid Symbol Naming predicts an additional 7%, Visual Perceptual Accuracy and Speed 1 (Discrimination) predicts 4%, and Visual Perceptual Accuracy and Speed 2 (Closure) and Word Memory each accounts for an additional 1% of the variance. After controlling for age, Phonological Awareness, Auditory Gestalt B (Synthesis) and Memory for Symbols significantly predict Reading Comprehension. Age accounts for 48% of the variance; Phonological Awareness accounts for 19% of the variance; and the three remaining variables predict an additional 1%, of the variance each, respectively. Complete statistical data are presented in Tables 7 and 8.

Research Questions 3 & 4

The third and fourth research questions address the relative capability of the various cognitive components as measured by the TODD to predict Terra Nova Spelling (Research Question 3) and the Reading Composite (Research Question 4), which is comprised of Vocabulary and Reading Comprehension. Phonological Awareness is the best predictor of Spelling, explaining 21% of the variance. The second best predictor of Spelling is Auditory Gestalt B (Synthesis), explaining an additional 4% of the variance. When age is entered first in the equation, age accounts for 5% of the variance; Phonological Awareness is the second best predictor of Spelling, accounting for 20% of the variance. Memory for Symbols and Auditory Gestalt B (Synthesis) account for 6% and 3% of additional variance, respectively. Complete statistical data are found in Tables 9 and 10.

Phonological Awareness is the only significant predictor of Reading Composite, accounting for 49% of the variance. After controlling for age, it accounts for 8% of the variance in Reading Composite. Phonological Awareness is the second best predictor of Reading Composite, contributing 46% of the variance. Visual Perceptual Accuracy and Speed 2 (Closure) accounts for an additional 3% of the variance. Tables 11 and 12 contain complete statistical data.

## 6. Discussion

The purpose of this study was to determine the relative predictive importance of cognitive constructs to predict reading ability. The underlying cognitive processes indicated by recent research to be fundamental to reading are phonological awareness, rapid automatic naming, which is related to processing speed, auditory short-term memory, auditory processing, visual memory, and visual processing. Scores from subtests assessing these processes were used to predict Letter-Word Calling, Decoding and Reading Comprehension as measured by the TODD. The second purpose was to examine how well the aforementioned underlying processes predict end-of-year reading achievement scores as measured by the achievement test used by the Tennessee State Department of Education, the Terra Nova.

Results are commensurate with current research which supports the predominance of phonological awareness and the relative importance of rapid automatic naming, auditory memory and processing in the prediction of reading. In addition, current findings support a small but significant influence of visual memory and processing in predicting and diagnosing dyslexia (Wolf, 1999 & Denckla & Cutting, 1999).

Inability to develop basic decoding and word calling skills constitutes the most common type of reading disability, and is often referred to as dyslexia. Emerging research findings emphasize the importance of phonological awareness in the acquisition

of these very basic reading skills (see Lyon, 1995 & Shaywitz, 1998). Phonological awareness is often implicated as the most important cognitive variable underlying development of early reading, and is sometimes described as awareness of and access to the sound structure of language. In fact, recent research has suggested a phonologic-deficit model of dyslexia in which lower-order linguistic (phonologic) functions necessary to decode and identify words “block access to higher-order processes and to the ability to draw meaning from text” (Shaywitz, 1998, p. 308). Therefore, deficits in phonological awareness impact significantly early acquisition of decoding and reading skills, and cause pervasive reading difficulties, regardless of intelligence and age. In fact, phonological awareness has been found to account for between 50% to 75% of the variance in beginning reading scores (see Pennington, 1991, & Elbro, Borstrom, & Peterson, 1998). And the link between phonological awareness and the basic skills assessed by the TODD are apparent from a task analysis of the demands of the subtests. That is, the basic reading skills subtests (Letter-Word Calling and Decoding) assess the ability to identify sounds associated with basic letters, syllables, and words. These are skills that are often considered operationalizations of the reading process.

Although Phonological Awareness is the strongest predictor of Letter-Word Calling, it is not the only significant predictor; Rapid Symbol Naming, Visual Perceptual Accuracy and Speed 2 (Closure), Auditory Gestalt B (Synthesis) and Word Memory account for additional variance. So, even though phonological awareness seems to be an essential element necessary to identify basic sound-symbol relationships, certain other

skills are also important. That is, the ability to perceive accurately and call quickly these grapheme/phoneme constituents is also one of the most important precursors of accurate, fluid reading, as indicated previously by Elbro, Borstrom & Peterson, (1998); Roberts & Mather (1997), Shaywitz (1996), and Cronin & Carver (1998).

Phonological Awareness is by far the most robust predictor of Decoding, the second criterion variable. In fact, the TODD's Phonological Awareness predicts Decoding better than it predicts Letter-Word Calling. Although Letter-Word Calling and Decoding subtests both assess beginning reading, they do so in a different manner. Decoding is defined on the TODD as the ability to orally produce the sounds of letters and to call nonsense words. On the other hand, Letter-Word Calling involves the recognition of familiar words. Decoding relies more on the awareness of the sound symbol relationships because the child is required to read phonetically regular nonsense words. Recent research has shown phonological awareness to be a better predictor of phonological recoding of nonsense words than decoding of real words. For example, results from a Danish study of adults with and without a history of learning problems, indicated the ability to call non-words matched individuals to reading histories better than real word reading and reading comprehension (see Elbro et al., 1998). The TODD's Phonological Awareness subtest requires discriminating between similar sounds and identifying sound additions or deletions from nonsense words. The similarities between the task demands of Phonological Awareness and Decoding likely account for the very strong predictive relationship between the two.

Advanced reading skills are also predicted strongly by phonological awareness. TODD subtests Phonological Awareness, Rapid Symbol Naming, Visual Processing Accuracy and Speed 1 (Discrimination), Visual Processing Accuracy and Speed 2 (Closure), and Word Memory are significant predictors of Reading Comprehension, and predict in that order (Research Question 2). These results are consistent with the findings from Cornwall (1992), who investigated the relationship between phonological awareness, rapid naming, and working memory; in particular, she examined the extent to which these cognitive variables are interrelated (i.e., all aspects of an overall phonological ability). Also, she examined the ability of phonological awareness, naming speed, and verbal memory to predict word attack (i.e., decoding) word identification, reading comprehension, and spelling for 54 nine-year-old children with reading disabilities. After controlling for age, socioeconomic status (SES), behavior problems and verbal IQ, phonological awareness best predicted word attack (i.e., decoding), spelling, and reading comprehension scores; however, rapid letter naming added significantly to the prediction of word identification and prose passage speed and accuracy scores; also, a word list memory task added significantly to the prediction of word recognition scores. Cornwall concluded that performance on tests of phonological processing, rapid naming and word-list memory added unique shares of variance in the academic achievement of reading disabled children, adding to the literature showing the power of phonological awareness, processing speed and memory to predict reading.



As in Cornwall's study (1992), phonological awareness was found to be the most significant predictor of decoding, spelling, and reading comprehension; however, other variables are also important in predicting reading. For example, the TODD's rapid automatic naming subtest, Rapid Symbol Naming, added significant variance to word recognition (Letter-Word Calling), decoding, and reading comprehension. Also, consistent with Cornwall's findings emphasizing the importance of memory, the TODD's Word Memory subtest significantly predicts word recognition (Letter-Word Calling) and reading comprehension. Although many of the conclusions reached by Cornwall are similar to those drawn from this study, there were some salient differences in the operationalization and methodology between the two. For example, the relationships among the dependent variables and reading skills in Cornwall's study were based on a sample of children referred for assessment due to significant spelling and reading impairments, whereas the sample in this study was randomly selected and is generally representative of the "normal" population. In addition, the measures in Cornwall's study were taken from a variety of instruments, i.e., the Wechsler intelligence Scale for Children-Revised (Wechsler, 1974), the Wide Range Achievement Test-Revised (Jastak & Wilkinson, 1984), and the Gray Oral Reading Tests-Revised (Wiederholt & Bryant, 1986) whereas all the measures for this study came from the TODD. Given these differences, the similarity in findings across the two studies attests to the capability of phonological awareness, rapid automatic naming, and memory to predict reading.

Cornwall's (1992) study indicated the relative importance of phonological awareness, processing speed and memory to predict reading; however, she did not include any visual processing measures in her study and could not evaluate the relative importance of that variable. In this study, both Visual Processing Accuracy and Speed subtests, Discrimination and Closure, were found to be significant predictors of Reading Comprehension; similarly, Visual Processing Accuracy and Speed 2 (Closure) was a significant predictor of Letter-Word Calling. Also, results from recent research suggest that visual processing speed and accuracy are related to rapid automatic naming, and these measures are significantly correlated in this study (see Table 2). Importantly, Galaburda, Menard, & Rosen (1994) assessed several cognitive abilities assumed to be fundamental to reading, including rapid automatic naming and the perception of shapes. They found that the group of cells responsible for rapid processing of shapes, the magnocellular system in the subcortical center in the thalamus, is compromised. Apparently this area within the thalamus is responsible for coordinating rapid visual processing, a basic skill necessary for acquisition of reading. Similarly, Chase (1997) found visual flicker-fusion performance of dyslexic children to be significantly delayed. That is, relative to peers, they exhibited longer interstimulus intervals (ISIs). These studies provide evidence that dyslexic children have slower rates of processing and decreased quality of visual information and that these limitations appear directly tied to central nervous system functioning. Consistent with the findings of Galaburda et al.

(1994) and Chase (1997), visual processing tasks and Rapid Symbol Naming from the TODD predict Letter-Word Calling and Reading Comprehension.

Similar to Rapid Symbol Naming, the visual processing measures in this study involved tasks amenable to verbal labels (since letters were often part of the stimuli); thus, these processing measures require, in part, auditory and memory processing (see Roberts & Mather, 1997). In addition, Rapid Symbol Naming and Visual Processing both measure automaticity using orthographic patterns. Badian (1998) investigated whether the addition of tests of phonological awareness, orthographic processing (Visual Matching) and naming speed to a preschool battery would improve prediction of reading. Her results indicate that sentence memory, visual matching and naming speed made significant contributions to the prediction of reading ability in second grade students. The Visual-Matching stimuli used in Badian's study and the visual processing measures in this study both include letters and therefore are considered to require both orthographic processing measure and phonological coding. Some of these cognitive variables have been related to reading ability by Wolf (1999), who found naming speed performance to be related to impaired fluency. She considered slow naming speed to be an index of slow fundamental processing. She hypothesized that the slow processing indirectly contributed to impaired fluency and comprehension of connected text (Wolf, 1999).

Long latencies between responses in a naming task suggest difficulty in acquiring automaticity, the ability to rapidly recognize and name objects, numbers, letters, words either in isolation or in context. Obviously skilled readers need to automatize the sounds

that comprise the symbolic code. Recent research on rapid automatic naming indicates that it requires the ability to connect the visual elements of language to the verbal, as well as the ability to rapidly process information. Some researchers define rapid automatic naming as the “efficiency of phonological code retrieval” (Denckla & Cutting, 1999, p. 33). For most educators, processing speed can be assessed fairly easily using rapid automatic naming procedures. However, even though rapid automatic naming is largely a processing speed measure, it is influenced by factors other than speed, such as phonological discrimination and working memory (Wolf, 1999). Felton (1992) indicated that rapid automatic naming, in concert with beginning sound discrimination and auditory conceptualization (manipulation of sounds in sequence), significantly predicted third grade reading outcome from 19 kindergarten predictor tasks.

Some of the cognitive components of the TODD obviously have elements in common, as indicated by the strong intercorrelations among the predictor variables (e.g., coefficients among Phonological Awareness, Word Memory, Rapid Symbol Naming, and Auditory Gestalt B [Synthesis] range from .48 to .74). All of these variables have an auditory component and are good predictors of TODD reading and are modest predictors of Terra Nova scores. For example, Word Memory (an auditory-based task) is critical in explaining the variance associated with Letter-Word Calling, Reading Comprehension (and Decoding when age is partialled out, as explained later). According to Wagner et al. (1993), the ability to perceive and manipulate phoneme-sized segments of speech facilitates completion of memory-span tasks. The ability to recognize words (Letter-

Word Calling), to decode unknown words and to comprehend (Reading Comprehension) meaning from text and the ability to retain words in working memory all rely on the efficiency of phonological coding in memory. Because many awareness tasks require accurate representation of phonological information in working memory, auditory limitations may directly affect performance of these tasks.

Investigation of the above-mentioned relationships depends upon the use of measures with strong psychometric properties and a sound methodology. This study relied to a considerable extent upon an experimental instrument, the TODD, to operationalize important cognitive and reading variables. Initial data support the robustness of the TODD measures. However, the use of an experimental test is supported if that instrument is significantly related to external measures that define important criterion variables. External measures are often more acceptable to readers who know the measures. For this reason, criterion measures from the Terra Nova (i.e., Comprehensive Tests of Basic Skills, Fourth Edition, 1989) were chosen to address the final two research questions.

Using the Terra Nova it is possible to determine the predictive capability of the TODD cognitive reading components (i.e., Spelling, Reading Composite). As mentioned earlier, the Terra Nova does not directly measure decoding. Spelling may be an appropriate measure of decoding as a reading ability because spelling and reading are closely related as Pennington (1991) states, "both use the same kind of codes but in different directions" (p. 59). Poor readers have difficulty sounding out words (phonics)

making reading slower and less automatic. Poor phonics ability affects the accuracy and automaticity of spelling as well. The spelling of new words cannot be learned and remembered without the phonological awareness of the rules and regularities of phonological codes in language (Pennington, 1991). According to Padget et al. (1996), deficits in phonological awareness, decoding and spelling are the primary characteristics of a child with dyslexia and that spelling “presents a clearer picture of grapheme-phoneme correspondences than word attack [Decoding]” (p. 62).

In this study, the importance of phonological awareness to spelling and overall reading is clear; Phonological Awareness significantly predicts the Terra Nova’s Spelling subtest (Research Question 3) and the Reading Composite (Research Question 4). However, an auditory processing measure, Auditory Gestalt B (Synthesis) also predicts Spelling. Auditory Gestalt B (Synthesis) requires the student to synthesize phonetically divided words by holding individual phonemes in short-term memory and then to put the sounds together to form a word. On the other hand, spelling requires the ability to segment sounds to identify the constituent letters in order to reproduce a word. Therefore, both auditory processing and spelling requires phonological coding in working memory (Greene, 1996).

Because TODD assessment relied on raw scores across a significant age range (5-12), and because these cognitive abilities are somewhat dependent on maturation, multiple regression analyses were computed with chronological age forced into the equations first. Variables that drop out of the predictive equation when age is

uncontrolled may not discriminate across the age range, i.e., they may be explained primarily by maturation only. For example, visual processing and rapid automatic naming do not significantly predict criterion variables after the variance associated with age is removed, with one exception: Visual Perceptual Accuracy and Speed 2 (Closure) significantly predicts the Terra Nova Reading Composite. Apparently, rapid automatic naming and visual processing are so highly correlated with age that they are subsumed by age when it becomes a predictor. In addition, this particular measure of processing speed (i.e., rapid automatic naming) may be inadequate in discriminating ability for older children since by the upper elementary level, children's familiarity with the stimuli used in naming tasks (i.e., letters and numbers) will be highly automatized despite reading ability (see Wagner et al., 1993). Also, the Rapid Symbol Naming subtest used in this study may have an inadequate ceiling; the accuracy scores were all very high regardless of age. Therefore, time becomes critical in differentiating automaticity of naming skill. But, the differences in times may not be sufficient for discriminating by age either.

The majority of the studies showing rapid automatic naming and visual processing to be significant predictors of reading ability have sampled individuals with reading disabilities. The sample in this study is generally representative of the normal population and may show a pattern of responding more influenced by age. In any case, these variables become less powerful when age is included, suggesting that they are influenced significantly by maturation.

With age partialled out, Phonological Awareness is again the strongest predictor of reading variables. For example, it is the best predictor of Letter-Word Calling, Auditory Gestalt B (Synthesis), and Memory for Symbols significantly predicts additional variance, respectively (Research Question 1). Phonological Awareness is the strongest cognitive predictor of Decoding (after age). Auditory memory is the only other variable that adds significant variance.

Results of this study show that the cognitive reading components most capable of predicting Reading Comprehension are similar to those that best predict Letter-Word Calling. The best predictors of Reading Comprehension are Phonological Awareness, Auditory Gestalt B (Synthesis), and Memory for Symbols, respectively (Research Question 2).

Importantly, auditory processing (Auditory Gestalt B [Synthesis]) and visual memory (Memory for Symbols) become capable of predicting reading when age is entered as a predictor (i.e., they predict Letter-Word Calling, Reading Comprehension and Spelling). Apparently they are less affected by the developmental process than are some other predictor variables. The auditory processing measure, Auditory Gestalt B (Synthesis), requires the child to hold individual phonemes in short-term memory and then put the sounds together to form a word. There is some evidence short-term auditory memory is affected by rate of articulation, which determines how much information can be rehearsed before it is lost (see Watson and Miller, 1993). Rate of articulation is measured by the speed with which children are able to pronounce phonetically difficult



words or phonetically regular nonsense words and automaticity (to break the phonetic code). This automaticity appears to be related to phonological awareness and memory. Memory difficulties affect negatively the ability to organize information for retrieval. However, recent studies have shown that the connection between phonological awareness and memory appears to decline by the elementary years, while reading comprehension and working memory appears to increase with age (see Stone & Brady, 1995).

Phonological awareness and auditory memory both rely strongly on the auditory modality and are strong predictors of reading. According to Shaywitz (1996), the Auditory Analysis Test is highly related to a child's ability to decode single words and is an important diagnostic indicator of dyslexia. This auditory task requires a child to segment words into their individual phonological units and then to delete specific phonemes. For example, the child must say "cat" without the "kuh" sound. Shaywitz's results were the same at all ages. The Auditory Gestalt subtests on the TODD require similar skills. The Auditory Gestalt B (Synthesis) subtest is closely related to the subtest used in Shaywitz's (1996) study because the child is required to identify a word based on the individual corresponding phonemes (i.e., identifying "kuh-aah-tuh" as "cat").

The results of this study are consistent with Shaywitz's study; Auditory Gestalt B (Synthesis) significantly predicts Letter-Word Calling, Reading Comprehension, and Spelling regardless of whether age is entered as a variable (but is somewhat more powerful when age is controlled for) and the Terra Nova Reading Composite when age is controlled for. In addition, there is increasing evidence that "good and poor readers

differ in the extent to which they use a phonetic representation (or some kind of speech code) to hold linguistic material (or other stimuli which can be speech coded) in short-term memory. These coding differences are apparent whether the linguistic material is presented visually or auditorily” (Blachman, 1982, p. 99).

Similar to Auditory Gestalt B (Synthesis), the visual memory measure, Memory for Symbols, relies on the ability to hold phonetic information in working memory. On the first three items on Memory for Symbols, examinees are shown a geometric shape for five seconds and then are instructed to choose the matching symbol contained in a multiple choice format with several incorrect but similar stimuli. However, all subsequent items show different combinations of letters from which examinees are to choose the correct sequence of letters from several options. Therefore, Memory for Symbols and Letter-Word Calling, Reading Comprehension and Spelling have common underlying components, i.e., the ability to identify letters and the ability to retrieve phonological codes for visually presented stimuli. For a child with letter identification deficits, strategies are unavailable to use to recall the order in which letters are presented since too much cognitive effort is put into identifying the letters. The ability to correctly call letters is dependent on their representation in long-term memory. Without this representation, the ability to store these lexical items in short-term memory will be compromised (Roberts & Mather, 1997).

With age partialled out, Phonological Awareness, Memory for Symbols and Auditory Gestalt B (Synthesis) significantly predict Terra Nova Spelling (Research

Question 3). As described earlier, the auditory processing subtest (Auditory Gestalt B [Synthesis]) requires the student to synthesize phonetically divided words by holding individual phonemes in short-term memory and then to put the sounds together to form a word. Similarly, Memory for Symbols requires the child to hold sequences of letters in short-term working memory and then to identify the sequence among several similar strings of letters. The rehearsal of these letter strings in working memory may tap auditory sequential memory as well as visual memory. According to the literature, spelling is an auditory sequential memory task. Sequencing is often an area of difficulty for dyslexics, particularly when it involves language (Greene, 1996).

When age is controlled, Phonological Awareness and Visual Perceptual Accuracy and Speed 2 (Closure) are the best predictors of the Terra Nova Reading Composite (Research Question 4). As discussed earlier, the visual-matching stimuli used in this study to measure visual processing includes letters and therefore requires orthographic processing and phonological coding because of the alphabetic nature of the stimuli (Badian, 1998). In addition, the speeded nature of this task relies on automaticity, which is crucial for comprehension. The Reading Composite has both a comprehension (Comprehension) component and a word identification (Vocabulary) component; thus, the task demands of this criterion variable are confounded. It is interesting to note that visual processing subtests are significant predictors of the TODD Letter-Word Calling and Reading Comprehension subtests when age is not part of the equation. However, visual processing drops out as a predictor for Letter-Word Calling and Reading

Comprehension when age is controlled. Thus, the Vocabulary component probably introduces something unique to the Reading Composite that makes the overall Composite sensitive to maturation.

The relationship among all these important cognitive variables may be reciprocal, leading to complicated interactions. Pencil and paper measures are used to operationalize the variables and to tease out the relative contributions of each to reading. In all probability they interact in an additive fashion to produce the complex task of reading.

#### Implications

These results support the contention that phonological awareness is the best predictor of reading and that rapid automatic naming, auditory short-term memory, auditory processing, visual memory and visual processing contribute significant additional variance. The strength of these predictions varies depending upon whether age is controlled. Teachers who provide remediation will benefit from knowledge of the building blocks for designing interventions appropriate for children presenting particular strengths and weaknesses.

Specific profiles of strengths and weaknesses may lead to more specific and effective intervention. For example, it has been suggested that students with phonologic processing problems (i.e., word attack or decoding) appear to benefit more from intensive phonics instruction than do students with orthographic processing difficulties (i.e., rapid automatic naming) who would more likely benefit from procedures that focus on the development of accurate and rapid word recognition and automaticity (Wolf, 1996).

Oakland et al. (1998) investigated the efficacy of a multi-sensory approach to remediating reading difficulties adapted from Orton-Gillingham's definition of dyslexia. Their results indicated that highly structured phonics instruction emphasizing the alphabetic system, drill and repetition to compensate for short-term memory and processing speed deficits, and multi-sensory methods to promote non-language mental representations were found to significantly improve word recognition and comprehension of dyslexics compared to a control group. Another method of remediation that is currently gaining popularity is the cross-modal approach, in which weak modalities are paired with strong modalities. For example, a visual processing deficit may be strengthened by having a child trace the word he sees thereby adding a kinesthetic approach (Hynd, 1986-87). In other words, once teachers can identify a child's strengths and weaknesses they can use this information to remediate difficulties by direct instruction and/or teaching the ability by pairing it with areas of strength.

A comprehensive assessment of dyslexia involves tests of language, spelling, reading, comprehension, memory and cognitive function. No single test score is conclusive for diagnosing dyslexia; rather data from a wide battery of tests must be synthesized to establish a "disparity between the person's reading and phonologic skills and his or her intellectual capabilities, age or level of education" (Shaywitz, 1998 p. 302). The TODD offers a single test battery with the cognitive and achievement components thought to be most predictive of dyslexia. The TODD offers the convenience of assessing children using one test battery, with the cognitive and achievement components

thought to be most predictive of dyslexia. With additional refinement and development, the TODD may become a useful tool to help psychologists and teachers design interventions based on specific strengths and weaknesses for individual profiles.

Limitations

The results of this study are consistent with findings from others who have investigated the crucial elements for diagnosing dyslexia; that is, phonological awareness and rapid automatic naming are the two most robust predictors of reading. However these results come from a small sample and from a restricted geographic location. Therefore, generalizability of results is limited.

Although results appear to provide support for the construct validity of the TODD, they should be considered tentative. The TODD is in development. Additional research is needed to further develop and refine the test.

**REFERENCES**

## REFERENCES

- Adams, M.J., & Bruck, M. (1995). Resolving the great debate. American Educator, 19, 7-12.
- Bathian, N.A. (1998). A validation of the role of preschool phonological and orthographic skills in the prediction of reading. Journal of Learning Disabilities, 31 (5), 472-481.
- Beck, I.L., & Juel, C. (1995). The role of decoding in learning to read. American Educator, 19, 8-12.
- Blachman, B.A. (1983). Are we assessing the linguistic factors critical in early reading? Annals of Dyslexia, 33, 91-109.
- Catts, H. W. (1986). Speech production/phonological deficits in reading-disordered children. Journal of learning Disabilities, 19, 504-508.
- Catts, H.W. (1991). Untitled. Topics in Language Disorders, 12(1), 1-16.
- Chase, C. (1997). A visual deficit model of developmental dyslexia. In Developmental Dyslexia: Neural, Cognitive, and Genetic Mechanisms. C. Chase, G. Rosen, and G.Sherman, eds. Baltimore: York Press.
- Cornwall, A. (1992). The relationship of phonological awareness, rapid naming, and verbal memory to severe reading and spelling disability. Journal of Learning Disabilities, 25, 532-538.



Cronin, V. & Carver, P. (1998). Phonological sensitivity, rapid naming, and beginning reading. Applied Psycholinguistics, 19, 447-461.

CTB MacMillan/McGraw-Hill (1989). Monterey, CA: Author. Comprehensive Tests of Basic Skills, Fourth Edition.

Denckla, M.B., & Cutting, L.E. (1999). History and significance of rapid automatized naming. Annals of Dyslexia, 49, 29-44.

Elbro, C., Borstrom, I., & Peterson, D.K. (1998). Predicting dyslexia from kindergarten: The importance of distinctness of phonological representations of lexical items. Reading Research Quarterly, 33-1, 36-60.

Felton, R.H. (1992). Early identification of children at risk for reading disabilities. Topics in Early Childhood Special Education, 12(2), 212-229.

Fletcher, J.M., Shaywitz, S.E., Shankweiler, D., Katz, L., Liberman, I.Y., Steubinh, K.K., Francis, D.J., Fowler, A.F. & Shaywitz, B.A. (1994). Cognitive profiles of reading disability: Comparisons of discrepancy and low achievement definitions. Journal of Education Psychology, 86 (6), 6-23.

Galaburda, A.M., Mernard, M.T. & Rosen, G.D. (1994). Evidence for aberrant auditory anatomy in developmental dyslexia. Proceedings of the National Academy of Sciences, 91, 8010-13

Gough, P.B. (1996). How children learn to read and why they fail. Annals of Dyslexia, 46, 3-20.

Gough, P.B., & Tumber, W.E. (1986). Decoding, reading, and reading disability. Remedial and Special Education, 7, 6-10.

Greene, J.F. (1996). Psycholinguistic assessment: The clinical base for identification of dyslexia. Topics in Language Disorders, 16(2), 45-72.

Hynd, C.R. (1986-87). Instruction of reading disabled/dyslexic students. Teacher Education and Practice, 3 (2), 17-33.

Jastak, S. & Wilkinson, G.S. (1984). Wide Range Achievement Test-Revised. Wilmington, DE: Jastak.

Kamhi, A.G., Catts, H., & Mauer, J.D. (1990) Explaining speech production deficits in poor readers. Journal of Learning Disabilities, 23, 632-636.

Kantowitz, B. & Underwood, A. (1999, November 22). Dyslexia and the new science of reading. Newsweek, 72-79.

Keim, D. (2000, October 8). Reading to get more attention from state. The Knoxville News Sentinel, pp.B1, B4.

Lieberman, I.Y., & Shankweiler, D. (1979). Speech, the alphabet, and teaching to read. In Theory and Practice in Early Reading, 2.

Lundborg, L., Olofsson, A., & Wall, S. (1980). Reading and spelling skills in the first school years predicted from phoneme awareness skills in kindergarten. Scandinavian Journal of Psychology, 21, 159-173.

Lyon, G.R. (1995). Toward a definition of dyslexia. Annals of Dyslexia, 45, 3-30.

Martin, R.C. (1995). Heterogeneity of deficits in developmental dyslexia and implications for methodology. Psychonomic Bulletin and Review, 2(4), 494-500.

Mathers, N. (1991). An instructional guide to the Woodcock Johnson Psycho-Educational Battery- Revised. Brandon, VT: Clinical Psychology Publishing Company.

McCallum, R.S., & Bell, S.M. (1999) The Test of Dyslexia and Dysgraphia. Unpublished test instrument.

Oakland, T., Black, J.L., Stanford, G, Nussbaum, N.L., & Balise, R.R. (1998). An evaluation of the dyslexia training program: A multisensory method for promoting reading in students with reading disabilities. Journal of Reading Disabilities, 31(2), 140-147.

Padget, S.Y., Knight, D.F., & Sawyer, D.J. (1996). Tennessee meets the challenge of dyslexia. Annals of Dyslexia, 46, 51-72.

Pennington, B.F. (1991). Diagnosing Learning Disorders; A Neuropsychological Framework. New York: Guilford Press.

Reid, G. (1998). Dyslexia. New York: John Wiley & Sons Ltd.

Roberts, R. & Mathers, N. (1997). Orthographic dyslexia: The neglected subtype. Learning Disabilities Research & Practice, 12 (4), 236-250.

Rooney, K.J. (1995). Dyslexia revisited: history, educational philosophy, and clinical assessment applications. Intervention in School and Clinic, 31(1), 6-15.

Shaywitz, S.E. (1996). Dyslexia. Scientific American, 78-84.

Shaywitz, S.E. (1998) Dyslexia. Current Concepts, 338 (5), 307-312.

Shaywitz, B.A., Fletcher, J.M., Holahan, J.M., & Shaywitz, S.E. (1992).  
Discrepancy compared to low achievement definitions of reading disability; Results of  
the Connecticut longitudinal study. Journal of Learning Disabilities, 25, 639-648.

Spafford, C.S. & Grosser, G.S. (1996). Dyslexia: Research and Resource Guide.  
Massachusetts: Allyn & Bacon.

Stone, B. & Brady, S. (1995). Evidence for phonological processing deficits in  
less-skilled readers. Annals of Dyslexia 51-77.

Tallal, P., & Fitch, R.H. (1993). Hormones and cerebral organization:  
Implications for the development and transmission of language and learning disabilities.  
In A.M. Galabruda (Ed.), Dyslexia and Development: Neurobiological Aspects of  
Extraordinary Brains. Massachusetts: Harvard University Press.

Terra Nova Technical Bulletin 1. (October 1997). Monterey, CA: CTB McGraw-  
Hill.

Vellutino, F.R., & Scanlon, D.M. (1987) Phonological coding, phonological  
awareness and reading ability: Evidence from a longitudinal and experimental study.  
Merrill-Palmer Quarterly, 33, 321-363.

Vellutino, F.R., Scanlon, D.M., & Tanzman, M.S. (1994). Components of  
reading ability: Issues and problems in operationalizing word identification,  
phonological coding, and orthographic coding. In Frames of Reference for the  
Assessment of Learning Disabilities: New Views on Measurement Issues. Baltimore:  
Paul H. Brookes Publishing.

Wagner, R.K. & Torgesen, J.J. (1987). The nature of phonological processing, and its causal role in the acquisition of reading skills. Psychological Bulletin, 101, 192-212.

Watson, B.U. & Miller, T.K. (1993). Auditory perception, phonological processing and reading ability/disability. Journal of Speech & Hearing Research, 36, 850-863.

Wechsler, D. (1974). Wechsler Intelligence Scale for Children - Revised. San Antonio, TX: PRO-ED.

Wechsler, D. (1991). Wechsler Intelligence Scale for Children III. San Antonio, TX: The Psychological Corporation.

Wiederholt, J.L., & Bryant, B.R. (1986). Gray Oral Reading Tests-Revised. Austin, TX: PRO-ED.

Wolf, M. (1996). The double-deficit hypothesis for the developmental dyslexias. Paper presented at the meeting of the Orton Dyslexia Society, Boston.

Wolf, M. (1999). What time will tell: Towards a new conceptualization of developmental dyslexia. Annals of Dyslexia, 49, 3-28.

Woodcock, R.W., & Mather, N. (1989). WJ-R Tests of Cognitive Ability-Standard and Supplemental Batteries: Examiner's Manual. In R.W. Woodcock and M.B. Johnson, Woodcock-Johnson Psycho-Educational Battery-Revised. Allen, TX: DLM.

**APPENDICES**

Table 1. Means and Standard Deviations of Cognitive and Reading Variables

	Means	Standard Deviations
Letter-Word Calling	26.11	10.53
Reading Comprehensions	20.76	10.44
Decoding	14.13	5.82
Phonological Awareness	14.72	4.83
Auditory Gestalt A (Closure)	8.12	3.66
Auditory Gestalt B (Synthesis)	10.69	3.5
Word Memory	5.11	1.98
Visual Perceptual Accuracy and Speed 1 (Discrimination)	20.91	4.57
Visual Perceptual Accuracy and Speed 2 (Closure)	17.26	6.13
Memory for Symbols	14.55	4.21

Table 2. Intercorrelations of Cognitive Reading Subtests and Dependent Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Letter-Word Calling	1.0												
2. Reading Comprehension	.86**	1.0											
3. Decoding	.82**	.64**	1.0										
4. Phonological Awareness	.88**	.74**	.91**	1.0									
5. Auditory Gestalt A	.45**	.38**	.38**	.38**	1.0								
6. Auditory Gestalt B	.72**	.67**	.62**	.66**	.50**	1.0							
7. Word Memory	.64**	.59**	.58**	.56**	.32**	.48**	1.0						
8. Visual Processing 1	.76**	.72**	.63**	.72**	.44**	.70**	.52**	1.0					
9. Visual Processing 2	.65**	.61**	.47**	.55**	.20*	.49**	.36**	.62**	1.0				
10. Memory for Symbols	.79**	.72**	.67**	.73**	.40**	.61**	.58**	.74**	.56**	1.0			
11. Rapid Symbol Naming	.80**	.73**	.71**	.74**	.47**	.58**	.57**	.65**	.51**	.71**	1.0		
12. Terra Nova Spelling	.48**	.40**	.51**	.47**	.04	.38**	.16	.32**	.17	.38**	.19	1.0	
13. Terra Nova Composite	.54**	.45**	.64**	.70**	-.03	.34**	.23*	.24*	.20	.34**	.20	.69*	1.0
14. Age	.75**	.70**	.48**	.54**	.38**	.54**	.53**	.65**	.63**	.62**	.70**	-.30**	1.0

\*p&lt;.05

\*\*p&lt;.01



Table 3. Multiple Regression Analyses Predicting Basic Letter-Word Calling from Cognitive Variables

Predictors	Beta	R <sup>2</sup>	Adjusted R <sup>2</sup>	F
1. Phonological Awareness	0.88	0.77	0.76	38.55**
2. Rapid Symbol Naming	0.35	0.82	0.82	23.75**
3. Visual Perceptual Accuracy and Speed 2 (Closure)	0.19	0.85	0.84	19.61**
4. Auditory Gestalt B (Synthesis)	0.18	0.86	0.86	16.58*
5. Word Memory	0.13	0.87	0.87	14.11*

N=105

\*p<.05

\*\*p<.01

Table 4. Multiple Regression Analysis Predicting Basic Letter-Word Calling from Cognitive Variables after Controlling for Age

Predictors	Beta	R <sup>2</sup>	Adjusted R <sup>2</sup>	F
1. Age	0.75	0.56	0.55	130.37**
2. Phonological Awareness	0.67	0.87	0.87	349.37**
3. Auditory Gestalt B (Synthesis)	0.14	0.88	0.88	254.53**
4. Memory for Symbols	0.13	0.89	0.89	200.89*

N=105

\*p<.05

\*\*p<.01

Table 5. Multiple Regression Analysis Predicting Decoding from Cognitive Variables

Predictor	Beta	R <sup>2</sup>	Adjusted R <sup>2</sup>	F
1. Phonological Awareness	.91	.83	.83	50.22**

N=105

\*\*p&lt;.01

Table 6. Multiple Regression Analysis Predicting Decoding from Cognitive Variables after Controlling for Age

Predictors	Beta	R <sup>2</sup>	Adjusted R <sup>2</sup>	F
1. Age	0.48	0.23	0.23	31.31**
2. Phonological Awareness	0.92	0.83	0.83	247.42**
3. Word Memory	0.11	0.84	0.832	172.64*

N=105

\*p<.05

\*\*p<.01

Table 7. Multiple Regression Analysis Predicting Reading Comprehension from Cognitive Variable

Predictors	Beta	R <sup>2</sup>	Adjusted R <sup>2</sup>	F
1. Phonological Awareness	0.74	0.55	0.54	12.39**
2. Rapid Symbol Naming	0.40	0.62	0.61	83.10**
3. Visual Perceptual Accuracy and Speed 1 (Discrimination)	0.31	0.66	0.65	66.00**
4. Visual Perceptual Accuracy and Speed 2 (Closure)	0.17	0.68	0.67	53.01*
5. Word Memory	0.15	0.69	0.68	44.76*

N=105

\*p<.05

\*\*p<.01

Table 8. Multiple Regression Analyses Predicting Reading Comprehension from Cognitive Variables after Controlling for Age

Predictors	Beta	R2	Adjusted R2	F
1. Age	0.70	0.49	0.48	97.65**
2. Phonological Awareness	0.51	0.67	0.67	104.54**
3. Auditory Gestalt B (Synthesis)	0.19	0.69	0.68	75.33*
4. Memory for Symbols	0.19	0.70	0.69	59.68*

N=105

\*p<.05

\*\*p<.01

Table 9. Multiple Regression Analysis Predicting Terra Nova Spelling from CognitiveVariables

Predictors	Beta	R <sup>2</sup>	Adjusted R <sup>2</sup>	F
1. Phonological Awareness	0.47	0.22	0.21	20.80**
2. Auditory Gestalt B				
(Synthesis)	0.24	0.05	0.04	13.44*

N=73

\*p&lt;.05

\*\*p&lt;.01

Table 10. Multiple Regression Analyses Predicting Terra Nova Spelling from CognitiveVariables after Controlling for Age

Predictors	Beta	R <sup>2</sup>	Adjusted R <sup>2</sup>	F
1. Age	-0.24	0.06	0.05	4.59**
2. Phonological Awareness	0.46	0.27	0.25	13.17**
3. Auditory Gestalt B (Synthesis)	0.29	0.34	0.31	11.79*
4. Memory for Symbols	0.22	0.37	0.34	10.31*

N=73

\*p&lt;.05

\*\*p&lt;.01



Table 11. Multiple Regression Analysis Predicting Terra Nova Reading Composite from Cognitive Variables

Predictors	Beta	R <sup>2</sup>	Adjusted R <sup>2</sup>	F
1. Phonological Awareness	0.70	0.50	0.49	69.90**

N=73

\*\*p<.01

Table 12. Multiple Regression Analyses Predicting Terra Nova Reading Composite from Cognitive Variables after Controlling for Age

Predictors	Beta	R <sup>2</sup>	Adjusted R <sup>2</sup>	F
1. Age	-0.30	0.09	0.08	7.03**
2. Phonological Awareness	0.69	0.56	0.54	44.73**
3. Visual Perceptual Accuracy and Speed 2 (Closure)	0.21	0.60	0.58	34.47*

N=73

\*p<.05

\*\*p<.01

**VITA**

Maripat M. Gettelfinger was born in Knoxville, Tennessee and graduated from Knoxville Catholic High School in 1983. She received the Bachelor of Arts in Psychology and English in 1982 from the University of Tennessee, Knoxville. Internship experiences were obtained through Cherokee Health Systems in Morristown, Tennessee, the Little Tennessee Valley Educational Cooperative Birth to 3 Program in Maryville, Tennessee, and South Doyle Middle School of the Knox County School System. The doctoral degree in School Psychology was received in December, 2000 from the University of Tennessee, Knoxville.