EFFECTS OF WORD TYPE, ORTHOGRAPHIC TYPE, AND WORD LENGTH ON DECODING AND SPELLING ABILITIES OF FOURTH GRADERS WITH AND WITHOUT READING IMPAIRMENTS

by

Joanne Carfioli Naylor, M.S., CCC-SLP

December, 2014

Director of Dissertation: Marianna Walker, PhD

Major Department: Communication Sciences and Disorders

The effects of word type (real, nonsense), orthographic type (phonetic, nonphonetic), and word length (1 to 5 syllables) on the decoding and spelling abilities (accuracy) of fourth-graders with and without reading impairments was investigated. This study was unique because the 23 participants were in one grade level (fourth grade) which controlled for age and reading experience. The participants, who varied in their single word decoding abilities, were separated into two reading groups, an average reading group and primary reading impairment group based on their performance on the *Woodcock Reading Mastery Test-III* (*WRMT-III*) Word Identification and Word Attack subtests. All 23 participants completed the three experimental tasks: a single word decoding task, a spelling decision task, and a written spelling task. The same stimuli, a total of 100 stimulus words, 50 real words and 50 nonsense words (word type), categorized by two orthographic types (25 phonetic, 25 nonphonetic), and five words for each of the five lengths (1-5 syllables) were used in each experimental task.

Word length had a significant effect on all three experimental tasks: 1) the single word decoding task, 2) the spelling decision task, and 3) the written spelling accuracy for both reading groups. Results included relationships between decoding accuracy, spelling decision accuracy, and written spelling accuracy for the two reading groups as a function of word type, orthographic

type, and word length. The decoding accuracy and spelling accuracy performance for the participants in the present study were characterized by a linear decrease in accuracy with an increase in word length. For the experimental tasks, the strongest correlations were found between the decoding and spelling accuracy for phonetic words regardless of word type (real words, nonsense words). Decoding accuracy results included a significant main effect of group, characterized by higher decoding accuracy by the average reading group for both word types compared to the reading impairment group. In the decoding accuracy, there was a significant three-way interaction for word type, orthographic type, and word length. Post hoc comparisons included higher decoding accuracy for shorter words (< 3 syllables) regardless of word type and orthographic type. Written spelling accuracy results included two significant three-way interactions for Reading Group x Word Type x Word Length and Word Type x Orthographic Type x Word Length. The average reading group accurately decoded and spelled more of the shorter words (≤ 3 syllables) than longer words (4 and 5 syllables) compared to the reading impairment group. Word type effects included more real words decoded and spelled accurately compared to nonsense words. Orthographic type effects included more proficient decoding and spelling of shorter real phonetic words (< 3 syllables) than real nonphonetic, nonsense phonetic and nonsense nonphonetic words, compared to words containing 4 and 5 syllables.

This study provided more detailed decoding and spelling information than current standardized assessment tools, characterized by reading group differences for word type, orthographic type, and word length. There is a need for an assessment tool that assesses both decoding and spelling accuracy and provides detailed error analysis using the same lexical/word stimuli categorized by word type, orthographic type, and word length for children with suspected reading impairment. Decoding and spelling accuracy measures are vital for the provision of detailed differential diagnoses and subtyping of reading impairments and spelling deficits. This detailed decoding and spelling data will also provide information critical for the provision of client-specific intervention.

EFFECTS OF WORD TYPE, ORTHOGRAPHIC TYPE, AND WORD LENGTH ON DECODING AND SPELLING ABILITIES OF FOURTH GRADERS WITH AND WITHOUT READING IMPAIRMENTS

A Dissertation

by

JOANNE CARFIOLI NAYLOR

Presented to the Faculty of the Department of Communication Sciences and Disorders

East Carolina University

In partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

COMMUNICATION SCIENCES AND DISORDERS

DECEMBER 2014

EFFECTS OF WORD TYPE, ORTHOGRAPHIC TYPE, AND WORD LENGTH ON DECODING AND SPELLING ABILITIES OF FOURTH GRADERS WITH AND WITHOUT READING IMPAIRMENTS

by

JOANNE CARFIOLI NAYLOR

APPROVED BY:

DIRECTOR OF DISSERTATION

____

Marianna M. Walker, Ph.D.

COMMITTEE MEMBER

____

Kevin O’Brien, Ph.D.

COMMITTEE MEMBER

____

Heather H. Wright, Ph.D.

COMMITTEE MEMBER

____

D. Erik Everhart, Ph.D.

INTERIM CHAIR OF THE DEPARTMENT OF COMMUNICATION SCIENCES AND DISORDERS

____

Kathy Cox, Ph.D.

DEAN OF THE GRADUATE SCHOOL

____

Paul J. Gemperline, Ph.D.

DEDICATION

This dissertation is dedicated to my family and friends. Mom, thank you for believing in me and supporting me. Diana and Alex, you have been my source of strength, inspiration, support, and love. I would not have been able to complete this journey without you. I promise I will be the best Dr. Mama ever! All of my friends who kept me going through this process, you are all precious to me. I wish you every success!

ACKNOWLEDGEMENTS

I am thankful for my wonderful committee members, Dr. Marianna Walker, Dr. Heather Harris Wright, Dr. Kevin O'Brien, and Dr. D. Erik Everhart, who have helped to guide me through this process with never-ending support and encouragement. I am thankful for the parents and children who agreed to participate in this study. I am thankful for all of the faculty, staff, and students at East Carolina University and friends abroad who have helped me by reading and editing, listening, and supporting me throughout this process. Dr. Joan Furey, you kept me going!

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

CHAPTER I: INTRODUCTION

Literacy skills are the key to personal, professional, and educational success. Children who are slow to acquire reading and spelling skills may be at high risk for educational and professional underachievement through the school years and into adulthood (Garnier et al., 1997; Whitehurst & Lonigan, 1998). Children need a solid foundation in the metalinguistic areas of phonemic awareness, orthographic awareness, and morphological awareness in order to become successful readers and spellers (Apel & Masterson, 2001; Bear & Templeton, 1998; Ehri & McCormick, 1998; Moats, 2000; Schlagal, 2001; Siegler, 1996). Oral vocabulary knowledge and naming speed also influence reading and spelling development (Bowers & Wolf, 1993; Denckla & Rudel, 1976; Nation & Snowling, 2004; Strattman & Hodson, 2005). All theories of literacy development differ in the manner (progressive or simultaneous) of the contributions of the metalinguistic areas, but they are consistent on the importance of phonemic awareness, spelling patterns (orthographic awareness), and meaning (morphological awareness) in the development of reading, written language, and spelling (Apel & Masterson, 2001).

Early identification and provision of focused intervention are needed to prevent reading and spelling deficits (Fowler, 1991; Stanovich & Siegal, 1994; Thomas & Senechal, 1998). A great deal of research focused on early-emerging reading difficulties for children in preschool to third grade has included variability because children are still developing decoding and encoding skills (Bear, 1992; Ehri & Wilce, 1987; Morris & Pearney, 1984). Chall (1983) and Jacobs (2003) reported there are students who appear to experience a "fourth grade slump" in reading achievement and spelling abilities. Leach, Scarborough, and Rescorla (2003) investigated reading and spelling performance for fourth and fifth graders who had late-identified (first seen in third grade) reading disabilities (RD) and normally achieving students. Leach et al (2003) reported three heterogeneous groups for both the early-identified and late-identified reading deficits groups, a group with word-level processing deficits and adequate comprehension skills, good word-level processing deficits and weak comprehension skills, and both weak word-level processing deficits and weak comprehension skills. In this study, Leach divided the children with late-identified reading deficits into three groups with 35% had word-level processing deficits with adequate comprehension skills, 32% had weak comprehension skills accompanied by good word-level processing skills, and 32% exhibited both weak word-level processing and weak comprehension skills (Leach et al., 2003). In comparison, the distribution of these three types of reading deficit had greater between group variation for early-identified reading deficits 49% word-level, 6% weak comprehension, and 46% both kinds of deficits (reading and comprehension). The use of separate tests were used to obtain scores which are based on different reference samples, so these percentages might differ somewhat from the case of all components were measured using a common task (Leach et al., 2003). In contrast, adolescent reading and spelling abilities and related sub-skills are highly stable and predictive of adult performance (Leach, Scarborough, & Rescorla, 2003; Maughan, Messer, Collishaw, Pickles, Snowling, Yule, & Rutter, 2009).

Variability in reading, spelling, and written language research results may be affected by the variety of assessment tools used, the stimuli types, differences in age groups, and the focus of the researchers. There is a need for research studies that assess both reading and spelling abilities of children and adults. Longitudinal studies that investigate the differences and similarities for both reading and spelling abilities across the life span would support clinical evidence based practice and provide speech-language pathologists and educators with valuable practical information to improve reading and spelling performance. In order to understand reading and spelling deficits, there is a need to identify the possible underlying causes, beginning with initial reading development.

Reading Development

Reading is a dynamic process that integrates decoding (word recognition) and comprehension. Decoding is a process that includes letter recognition, phoneme-grapheme knowledge, orthographic knowledge, word recognition, morphological knowledge, and semantic knowledge (Plaut, 2005), allowing for contextual decoding and resulting in reading fluency. Irwin (1986) defines reading comprehension as "the process of using one's own prior experiences and the writer's cues to infer the author's intended meaning. This process (reading comprehension) can involve understanding and selectively recalling ideas in individual sentences, inferring relationships between sentences, organizing ideas, and around summarizing ideas, and making inferences. Decoding and reading comprehension work together and can be controlled and adjusted by the reader as required by the reader's goal processes and the total situation in which comprehension takes place."

Theories of Reading Development

There are multiple models of reading: bottom-up, top-down, schema theory, metacognitive. The Bottom-up processing theory includes the letters, words, and language features in the text are decoded while reading, and through this process, readers understand intensive and local meaning of the text (LaBerge & Samuels, 1964). The Top-down theory

(Goodman, 1967; Smith, 1971, 1982) depicts reading as a dialogue between the reader and the text which involves an active cognitive process in which the reader's background knowledge plays a key role in the creation of meaning (Tierney and Pearson, 1994). Schema Theory (Rumelhart, 1975) posits that previous reading experiences lead to the creation of mental frameworks (stored in memory) that help a reader make sense of new experiences and aids comprehension. Meta-cognition involves thinking about what one is doing while reading in addition to decoding which aids in reading comprehension.

In contrast to the aforementioned models, the Simple View of Reading (Gough & Tunmer, 1986) addresses the processes involved in reading: decoding and linguistic comprehension. Decoding involves a word recognition process that transforms print into words (Gough & Tunmer, 1986; Hoover & Gough, 1990). Linguistic comprehension is the process by which words, sentences, and discourses are interpreted (Gough & Tunmer, 1986). Decoding and linguistic comprehension are not mutually exclusive processes, but are interdependent, so "reading" does not occur if either decoding or linguistic comprehension is not occurring (Gough & Tunmer, 1986; Hoover & Gough, 1990; Kamhi & Catts, 2005).

A Simple Model of Predicting Diagnostic Profiles relating phonological language skills at the sound/word level with nonphonological language skills at the sentence/discourse level was adapted from research by Bishop and Snowling (2004), and Catts and Kamhi (2005) by Nelson (2010). Typical development was characterized by high phonological skills at the sound/word level and high-nonphonological language skills at the sentence/discourse level. Dyslexia was characterized by low phonological skills at the sound/word level and high-nonphonological abilities associated with decoding deficit in reading but intact listening comprehension skills. Language impairment was characterized by low phonological skills at the sound/word level and low nonphonological language skills at the sentence/discourse level and across language levels and modalities. Finally, specific comprehension was characterized by low phonological skills at the sound/word level and high-nonphonological language skills at the sentence/discourse level. Catts, Hogan, and Fey (2003) found 36% of poor readers in both second grade and fourth grade met the qualifications for dyslexia, 36% were diagnosed with a mixed reading deficit (both decoding and comprehension deficits), and 15% of poor readers had intact decoding skills with reading comprehension deficits. In second grade, 32% were diagnosed with dyslexia, 36% with a mixed reading deficit, 16% with specific comprehension deficits, and 15% with nonspecified reading deficits. Fourth grade results included 22% with dyslexia, 33% with mixed reading deficit, 31% with specific comprehension deficits, and 14% with nonspecified reading deficits. Twenty-seven (27%) to twenty-nine percent (29%) of the children met the criteria for poor readers which is more than the national population of sixteen percent (16%) (Catts, Hogan, & Adlof, 2004). Catts and colleagues (2004) reported results for poor readers in their EPI-SLI study for tests of word recognition, listening comprehension, and reading comprehension. Differences in the reading abilities of children between second and fourth grade may be the result of focused intervention, differences in reading materials, and changes in the child’s decoding skills.

The development of reading may be affected by multiple internal and external factors (e.g., genetic and environmental*).* Genetic factors include the presence of congenital abnormalities at the perceptual level, such as visual and/or hearing deficits, and comorbid deficits including but not limited to attention-related deficits, such as Attention-Deficit Disorder (ADD) will affect both reading and spelling development (Stevenson, Langley, Payton, Worthington, Ollier, & Thapar, 2005; Stevenson, Graham, Fredman, & McLoughlin, 1987). Environmental factors, such as early exposure to print during joint-book reading activities, and supported school-based literacy activities have positive effects on literacy development (Bruck, 1990, 1992; Cunningham & Stanovich, 1997; Denton, Reaney & West, 2001; Maughan et al., 2009; Rodgers, 1986; Snow, Burns, & Griffin, 1998).

Stages of Reading Development

There are multiple stage theories of reading development (Chall, 1983; Ehri, 1998, 1999, 2002; Frith, 1985; Gough & Hilliner, 1980; Mason, 1980; Marsh et al., 1981; Seymour & Duncan, 2001; Stuart & Coltheart, 1988) which are similar in the belief that there is a progression from learning fundamental pre-reading skills to higher level reading skills, but vary in the number of development stages (two to six stages). Ehri (2004) provided a schematic summary of the Approximate Relationships between Different Stage/Phase Theories of Learning to Read (Table 1).

Table 1: Stage/Phase Theories of Learning to Read (adapted from Ehri, 2004)

Proponents	**Frith (1985)**	**Ehri (1998, 1999, 2002)**	**Chall (1997)**
1. Pre-reading	Logographic	Pre-alphabetic	Stage 0: Preliteracy
2. Early Reading		Partial Alphabetic	
3. Decoding	Alphabetic	Full alphabetic	Stage 1: Decoding
4. Fluent Reading	Orthographic	Consolidated Alphabetic, Automaticity	Stage 2: Confirmation of Fluency Stage 3: Learning New Information Stage 4: Multiple Perspectives Stage 5: Construction and Reconstruction

Chall (1997) provided six stages of Reading Development along with general relative age ranges because there are variations in development and decoding begins before the age of six with the provision of early intervention and kindergarten programs. In Stage 0 the Pre-reading/literacy socialization generally occurs between birth to six years of age. Children learn the conventions of print during parent-directed reading activities. The children learn the relationship between printed words on the pages of books with the words the parent is saying during the book reading. Children also learn the conventions of reading including how to hold a book, how to turn the pages, and that English text is read from left to right with different types of stress and intonation.

In Stage 1, the Decoding Stage occurs from age six to seven which usually corresponds to children in kindergarten and first grade. Children are taught and learn the letters of the alphabet and the relationship between the letters that form words and with sounds that are produced when reading the word (phoneme-grapheme relationships). The children learn to phonologically decode words in books, written assignments, and during word play games with parents. Children also learn to recognize orthographic patterns, letter sequences, which are experienced most frequently and store them in the mental lexicon. This happens for words that are not easily decoded phonologically or are memorized.

During Stage 1(Chall, 1997), the presence of a dual-route model of reading (decoding) becomes evident (Coltheart, 1987; Ellis, 1984). Researchers (Coltheart, 1987; Ellis, 1984; Rapcsak et al., 2007; Rastle & Coltheart, 2000) have investigated the differences in both accuracy and rate of decoding using read words and nonsense words based on their orthographic type (phonetic and nonphonetic) and provided support for the presence of two independent and interrelated routes in the brain for decoding known as the phonological route and the visual-lexical route. The phonological route is used to learn the relationship between letters and sounds and aids in the decoding of words, such as “kit” that have a single letter to sound ratio. The visual-lexical route is used when beginning readers need to learn and memorize sound patterns and words that do not have a one-to-one letter sound ratio commonly referred to as sight words. The *Dolch List of 220 Basic Sight Words* (1936) is composed of words from children’s literature that can either be phonologically decoded (e.g., at, not) or sight-words (e.g., the, to) that cannot be phonologically decoded and need to be memorized (Dolch, 1936). Frequent exposure and experience with reading and decoding high frequency words, then encoding and storing of both types of words (phonologically decodable and sight words) allows the developing reader to increase their mental lexicon and aids in the quick recognition (reading/decoding) and retrieval of words during both reading and spelling activities. Eventually, with multiple successful exposures, words that were initially phonologically decoded become part of the sight-word lexicon aiding in an increase in both accuracy and rate of decoding (Samuels, 1979; Horst, Parsons, & Bryan, 2011). In school, children are taught rules for acceptable ways to blend letters to form word roots and word families (e.g., “- an”), the use and spelling of morphemic affixes (i.e., prefixes “un-” and suffixes “-ing”), and how to segment larger words into smaller chunks. Once the word roots and affixes have been learned and stored, they are able to be retrieved using the visual-lexical route of decoding. The visual-lexical form of decoding is more efficient than phonological decoding because it allows the reader to devote less time and cognitive resources to decoding words in text and more resources to comprehending what is being read (Ehri, 2002; Share & Stanovich, 1995).

Stage 2 Confirmation of Fluency (Chall, 1997) follows the decoding stage and occurs between the ages of eight and nine, or in second and third grade when children are able to use both the phonological route and visual-lexical route flexibly depending on the type of word that is encountered in reading. Children develop decoding fluency and there is an increase in the reading rate and the flexible use of both phonological decoding and sight word decoding (i.e., whole word decoding) by retrieving stored orthographic representations. This increase in the transition between phonological and visual/lexical sight word decoding affects the rate and accuracy of fluency. Reading comprehension also increases during this stage because children are able to use less cognitive processing to decode words and focus on the concepts and meaning of what they are reading.

Stage 3 Learning New Information from Reading (Chall, 1997), generally occurs between the ages of nine and ten years, or in third grade to fourth grade. During stage 3 (Chall, 1997) reading comprehension becomes predominant, and reading fluency (the accuracy, rate, and prosody of reading) decreases. The need to use phonological decoding for words is reduced with practice, and the reader is able to focus on the meaning of what is being read, such as fact-based information encountered in the science and social studies (Chall, 1997; Cook & Cook, 2009). Children are able to read and follow written instructions, and learn from reading materials that contain fewer pictures, more words, more complex text structures (paragraphs, chapter, etc.) and require the interpretation of information.

Samuels (1979) presented research that investigated the benefits of repeated readings of simple passages to increase fluent reading by children with decoding deficits. Samuels separated fluency into two components – accuracy of word recognition and reading speed. Since there appears to be a trade-off between accuracy and speed, there was a need to reduce the emphasis on accuracy and increase the emphasis on speed. When children are more focused on accuracy, there is a higher probability that the pace of reading will decrease to reduce the possibility of making mistakes. Results included an increase in reading fluency (words per minute) and decrease in decoding errors with each additional reading of passages. When a child has more experience successfully decoding words that are both phonologically decodable and sight words, they are able to store word structures in the mental lexicon and use short term working memory to decode words that are not familiar. Eventually, the child is able to read more fluently and accurately and have cognitive resources available for reading comprehension (Samuels, 1979).

The last two stages of Chall's Reading Development (1997) are Stage 4: Multiple Perspectives and Stage 5: Construction and Reconstruction. During stages 4 and 5, the reader expands his basic reading ability inventory to include figurative language and higher level language concepts. Successful readers continue to expand their knowledge by reading factual books and articles, novels, research articles, and political documents. Readers also learn to understand and take both the perspectives of the characters involved in the stories and the perspectives of the writer during the construction and reconstruction stage. The reader's progression from Stage 0: Pre-reading to Stage 5: Construction and Reconstruction (Chall, 1997) will hopefully be fluid with support from parents, educators, and peers.

There is a relationship between the development of reading and spelling (Cassar & Treiman, 1997; Swank & Catts, 1994; Waters, Bruck, & Seidenberg, 1985). Two prominent and opposing views concerning the role of spelling-sound information in reading emphasize different routes of decoding accuracy and spelling accuracy. The mediate access models (e.g., Gough, 1972; Rubenstein, Lewis, & Rubenstein, 1981) include the reading as the generator of the phonological code for a word on the basis of knowledge of spelling-sound correspondence; this code is then used to access entries in the mental lexicon. In contrast, direct access models (e.g., Forester & Chambers, 1971) state that words are first recognized visually with the phonological code subsequently read out of memory storage. Simon and Simon (1973) suggested there are two corresponding routes used in spelling. The spelling of a word could be read out of its corresponding mental lexicon representation, or it could be derived through the application of sound-to-print rules (Waters et al., 1985).

Waters and colleagues (1985) researched recognition of regular words that are phonologically decodable (e.g., back) and irregular words that are not phonologically decodable (e.g., have) by children in third grade with differing reading and spelling abilities. If spelling-sound knowledge is used in word recognition, regular words should be easier to recognize than irregular/exception words. If readers recognize words on a visual basis and look up their pronunciations, then regular and irregular/exception words should be read with equal capability. Performance of Canadian (Montreal) children with and without reading and spelling deficits determined by psychometric testing, the *Stanford Diagnostic Reading Test* (1984), and *the Wide Range Achievement Test* (*WRAT*: Bijou & Jastak, 1978) were subtyped into three groups: good (good readers and good spellers), mixed (good readers and poor spellers), and poor (poor readers and poor spellers). Results indicated that all children attempted to use spelling-sound correspondences in both reading and spelling real (high frequency regular, low frequency regular, ambiguous words, exception words with multiple pronunciations, and strange words) and nonwords that were derived from the real words. The stimuli for the reading task included a list of real words and nonwords with nine stimuli from each of the five categories a total of 90 words. The stimuli for the spelling task were 96 nonwords that were derived from the regular words guaranteeing only one correct spelling for each word. Each child read the real words and nonsense word lists on a computer screen. Reading response latencies were timed from the appearance of the stimuli on the screen. Correct responses and number of errors were analyzed. Responses were recorded in real time and digitally-recorded for review. Spelling tasks for the four lists of spelling words (three lists of real and one list of nonwords) were presented over four sessions in a group. Spelling accuracy and mean number of errors were analyzed using repeated measures analysis of variance with word class (5 classes) as the within-subjects factor and group (good, mixed, poor) as the between-subjects factor. Spelling errors were classified into four categories: phonetic, nonphonetic, orthographically legal and illegal. Results supported the use of similar processes, spelling-sound information for both reading and spelling tasks. In this study, the child's use of sound-spelling information differentiated younger good readers from poor readers and younger good spellers from poor spellers. This supports the use of spelling-sound correspondences underlies both good reading and spelling skills. Reading and spelling errors of these third graders were the result of a general problem in the knowledge and use of sound-spelling correspondences (Waters et al., 1985).

Ehri (2000) also reported that learning to read and learning to spell rely on much of the same underlying knowledge, such as the relationship between letter and sounds which are used to form mental representations. Successful learning and storage of letter-sound relationships have been found to support reading development, spelling development and written language development. Children need to have correctly-spelled phonological and visual representation of words (sight-words, Cassar & Treiman, 1997; Swank & Catts, 1994) in memory or they will have more difficulty recognizing words in print (Ehri, 1998) and have problems with decoding words and constructing words during spelling activities (Snow, Griffin, & Burns, 2005). It is important for reading and spelling abilities to be assessed in order to investigate the relationship and determine if development is following a positive path.

Spelling Development

Spelling is a multifaceted phonological or metaphonological task (Clarke-Klein & Hodson, 1995) that is dependent on the integration of phonological, morphological, semantic, and orthographic knowledge (Fischer, Shankweiler, & Liberman, 1985), and has been shown to interrelate with (Snowling, 1985), but develop independently of reading (Goswami & Bryant, 1990). Perfetti (1997) defines spelling as "the encoding of linguistic forms into written forms. The linguistic forms – phonological strings, morphemes, and words – are provided by spoken language. The written forms are provided by the writing system and inventory of graphic devices" (p.22).

Spelling, like reading and writing, is a crucial component of functional literacy (Norton, Kovelman, & Petitto, 2007). Letter knowledge is also important in handwriting and spelling

(Abbott & Berninger, 1993). Word recognition, the ability to correctly read words may facilitate correct spelling and writing strengthening the probability that children will learn to represent letters forms correctly in memory and develop routines for their automatic retrieval from memory. The ability to read words correctly may facilitate the creation of precise, word-specific representations in long-term memory; those representations can be accessed during written spelling tasks and increase the probability of spelling words correctly – especially words with silent letters or alliterations in phoneme-spelling relationships that must be learned for specific word contexts (Berninger, Abbott, et al., 1998; Berninger, Vaughn, et al., 1998; Berninger et al., 2002). Additionally, the ability to learn morphemic patterns is also important to higher-level spelling of multisyllabic words, which will aid higher-level writing and the production of longer more sophisticated written compositions.

Clarke-Klein and Hodson (1995) have reported that good spellers are more sensitive to the structure of languages, are better able to manipulate and think about language (metaphonological knowledge), and learn linguistic complexities compared to poor spellers. All children must have good phonemic and phonological awareness to become proficient readers and spellers. Children need to have phoneme-grapheme awareness in order to correctly spell words in print, and the gross and fine motor skills to write the letters in print on paper or type into a computer to form words, sentences, in order to compose stories, complete documents, and share information via social media (e.g., cell phones, email). The development of these neurolinguistic and psycholinguistic skills, in addition to motor programming needed to become a proficient speller occurs over time and is supported by many years of research (Frith, 1980; Masterson & Apel, 2005; Norton, et al., 2007; Treiman & Bourassa, 2000).

Reading and spelling are reciprocal processes that develop during childhood and continue to develop and change throughout the lifespan. Stage theories of spelling development have been proposed by researchers (e.g., Ehri, 1986, 1994; Frith, 1980) to explain the learning process and allowing for the determination of areas of need across age groups. Spelling development occurs along with reading development, but somewhat out of phase (Snowling, 1985). It is possible for a child to read logographically and spell alphabetically; resulting in the child being able to write regular words but not read them (Bryant & Bradley, 1980). A beginning reader may also progress to become competent orthographic reader, but still have alphabetic spelling (Frith, 1980). Similar to reading development, there are many factors that affect spelling development, such as motor ability, attention, oral and written language experience, and environment.

Proficient spelling is the result of phonemic coding skills and differences in learning style and modality reflect different level of skill and/or effects of instruction (Gough & Walsh, 1991) within a range of "normal" accepted differences. Researchers have reported that young children rely heavily on phonological information for spelling words (Steffler, Varnhagen, Friesen, & Treiman, 1998; Treiman, 1993; Varnhagen, Boechler, & Steffler, 1999). Children need to have correctly spelled phonological and visual representations of words (sight words, Cassar & Treiman, 1997; Swank & Catts, 1994) in memory or they will have more difficulty recognizing words in print (Ehri, 1998) and problems with decoding words during reading and constructing words during spelling activities (Snow, Griffin, & Burns, 2005).

Theories of Spelling Development

Three theories of spelling development have been proposed during the past 35 years, the Amalgamation Theory (Ehri, 1986), the Connectionist Model (Seidenberg & McClelland, 1989), and the Dual Route Theory (Ellis, 1993). All three theories support the need for and presence of two separate yet complementary routes for spelling development.

The Amalgamation Theory as proposed by Ehri (1986) emphasizes the degree of association between spelling and reading and the interconnectedness between word knowledge aspects. Word identities have several features (phonological, morphological, orthographic, semantic, and syntactic) that become strongly bonded when they are learned leading people to base their beliefs about words on their knowledge of spelling rather than pronunciation.

The Dual-Route Theory of Spelling (Barry, 1994; Coltheart et al., 2001; Ellis & Young, 1988; Morton, 1980) describes the interactive network of the brain as an information processing system with different components of words and sounds stored in different locations (modules) in the neural network underlying written language production of letter sequence and facilitate the development and storage of visual images, motor plans, and meaning for spelling words. The two modules (phonological module and visual-orthographic module) are connected by neural communication pathways that can operate independently of each other. The Phonological module holds the sounds structure of words and the Visual-Orthographic module holds information about the letters in printed words (Ellis, 1993; Frith, 1980a; Stuart & Coltheart, 1988). The brain establishes two independent routes during the decoding development which transfer information from a meaning processor via either the phonological or visual-orthographic route for decoding and/or spelling a word (Moats, 1995) which is evident in recent functional magnetic resonance imaging research (Norton, Kovelman, & Petitto, 2007). There are fewer researchers that report the neural foundations of spelling compared to researchers who have investigated the neural foundations of reading (Norton et al., 2007).

The Phonological processor (speech output lexicon) stores the sounds that make up the words and aids in correct spelling. The most common graphemes or spelling patterns are in this module, which helps with spelling new/unknown words phonetically but not necessarily correctly. The visual-orthographic module (graphemic output lexicon) stores words whose spellings that have been memorized. If retrieval of a word from orthographic memory is stimulated by a partial phonological cue, a similar word may be written (e.g., rich for ridge). If all of the letters in the intended word are not known, a visually similar word (i.e., visual gestalt) may be retrieved with omitted letters or incorrectly ordered letters (e.g., *wuold* for *would*). The use of two routes for processing grapheme-phoneme (letter-sound) and retrieving phoneme-grapheme (sound-letter) relationships is a still a point of controversy for neuropsychologists (Rapcsak et al., 2007).

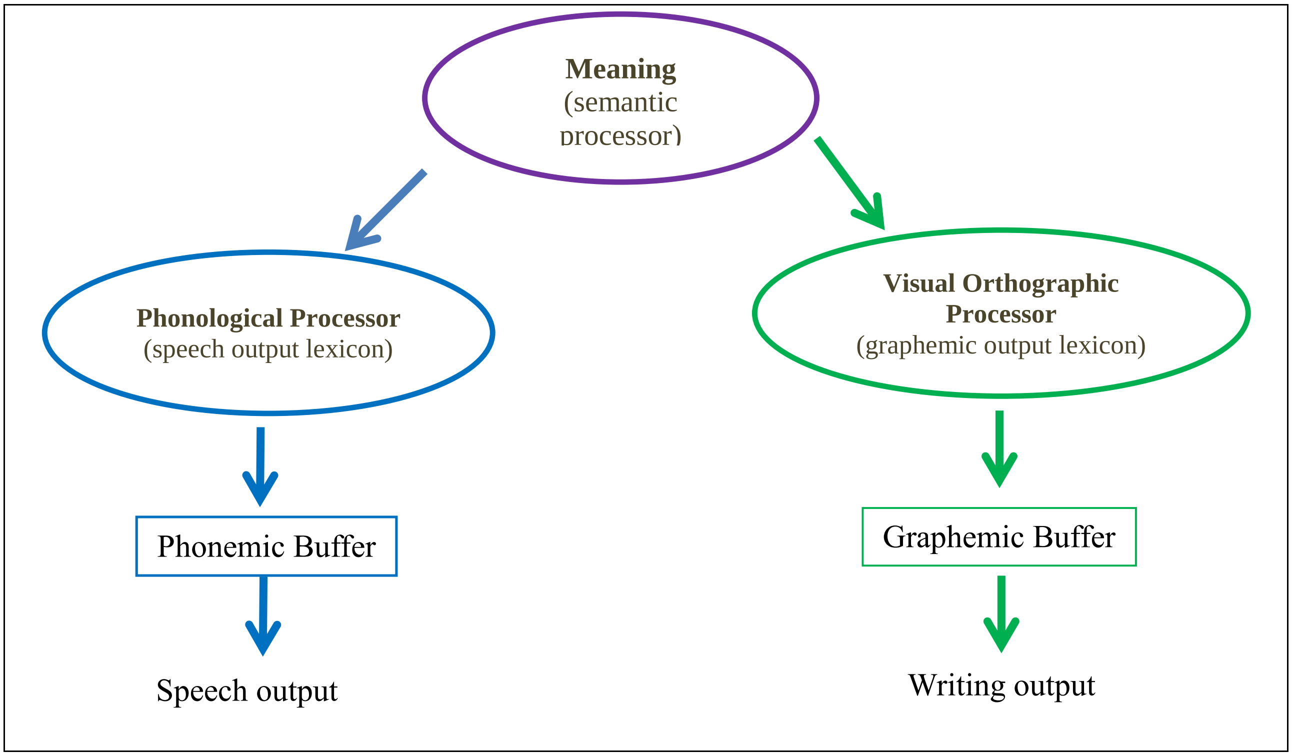

Figure 1: Simple model of processing components of spelling production (Ellis, 1993)

Connectionist models were formed to solve problems evident in the dual-route theory (Adams, 1990; Seidenberg & McClelland, 1989; Van Orden, Pennington, and Stone, 1990). These models emphasize that language learning depends on the extraction and recall of relationships among events or phenomena. The importance of each processor facilitates the growth and use of other processors for learning to read and spell. Like the dual-route model there are separate neural processors responsible for storage and retrieval of phonological, orthographic, and semantic information as reading and writing are done. There are neural connections between basic units that are made and strengthened through exposure and use.

Lexical units with stronger connections are retrieved faster and easier than those with weaker associative connections (Adams, 1990; Seidenberg and McClelland, 1989; Van Orden, Pennington & Stone, 1990).

In 2001, a shared-components dual-route model (SCDRM; Tainturier & Rapp, 2001) was proposed to describe the cognitive processes involved in both reading and spelling. In this model there is a common orthographic lexicon used for reading and spelling familiar words and a single non-lexical module that mediates both grapheme-phoneme (GP) and phoneme-grapheme (PG) conversion. This study will be focused on the SCDRM (Rapcsak et al., 2007; Figure 2) as the model for reading and spelling learning and processing.

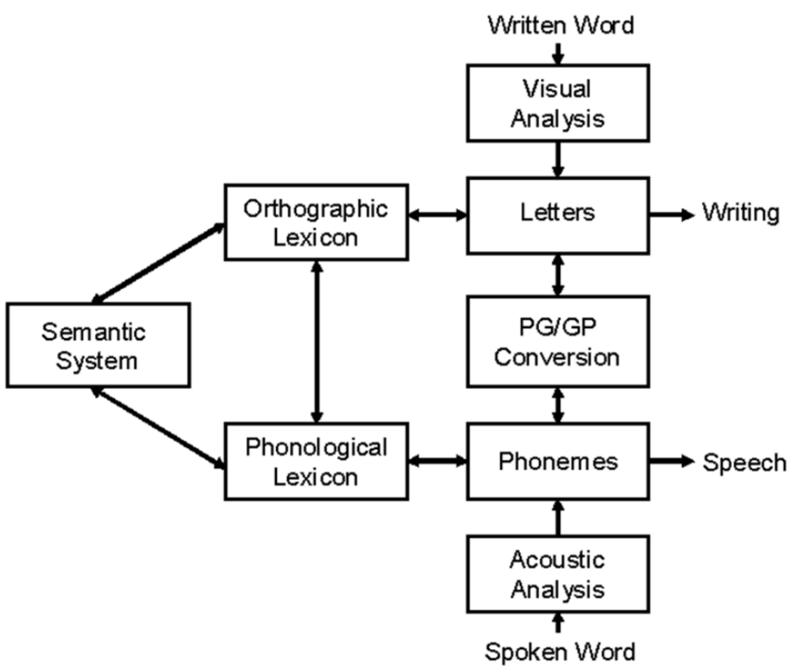

Figure 2: Shared-components dual-route model (Rapcsak et al., 2007)

Stages of Spelling Development

Spelling development in English occurs along with reading development somewhat out of phase (Snowling, 1985). The stages of reading (Chall, 1997) and spelling (Ehri, 1986; 1990) development are presented in Figure 3. A beginning reader may progress to become competent orthographic reader, but still have alphabetic spelling (Frith, 1980). Bryant & Bradley (1980) reported children can correctly spell and write regular words but not correctly read them. There are many external and internal factors that affect spelling development (e.g. environment, language, attention, experience) that are similar to reading development and spelling development. English, Hebrew, and French are known as opaque languages, meaning they have phonemes that can be spelled in multiple ways, resulting in a high degree of spelling inconsistency (e.g., /f/ = if, cuff, rough, graph), which may affect spelling development. The spelling variations in each of these languages are cited as one of the main reasons why spelling development lags behind reading development (Bosman & Van Orden, 1997; Geva, Wade-Woolley, & Shany, 1993; Sprenger-Charolles, Siegel, & Bonnet, 1998). Additionally, the method of spelling instruction can also affect spelling performance (e.g., phonics, sight words, and whole language) in addition to home environmental and genetic factors. In this study, the spelling experience and reading experience of the participants was controlled for because they were from the same grade level.

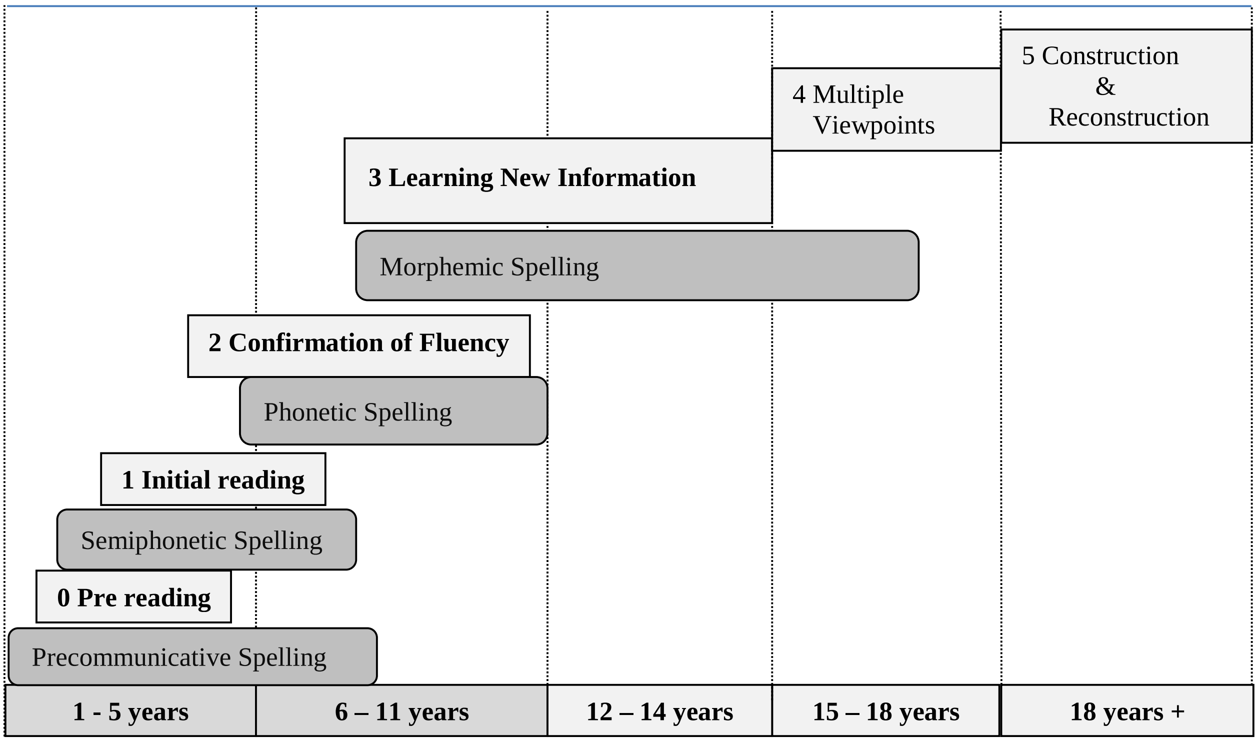

Figure 3: Stages of Reading (Chall, 1997) and Spelling Development (Ehri, 1986, 1990), the stages of reading are light gray and stages of spelling are dark gray.

Charles Read (1971) examined preschool children's knowledge of English orthography by examining the children's "invented spellings". He found that children produced common and systematic spellings for unknown words (Young, 2007). Beers and colleagues (Beers, Beers, & Grant, 1977; Beers & Henderson, 1977; Young, 2007) used error analysis to study children's invented spellings and identified specific stages of spelling development. The stages follow the ordering principles of English spelling system: first knowledge of the alphabet and letter sounds, followed by understanding of letter patterns and sequences, and then awareness of the meaning relationships between English words (Henderson & Templeton, 1986). Beers et al. (1977) reported spelling errors children make while writing are not random, there are identifiable stages of orthographic awareness through which children pass as they become more proficient in their writing, although at varying rates (p. 231). Once a child masters the skills in one stage, they progress to the next stage and do not revert to earlier stage characteristics (Gentry, 1982; Lutz, 1986).

Ehri's (1986) sequence involves five spelling development stages: Precommunicative (ages 1-7 years), Semiphonetic (4-9 years), Phonetic (6-12 years), and Morphemic (8-18 years). In the Precommunicative Stage, which occurs between the ages of one and seven years, or in preschool to first grade, children use letter forms in different patterns, left to right, up and down, and the meaning of those letters and words is assigned by the writer (Logographic, Frith & Frith, 1983). In the Semiphonetic Stage, which generally occurs between four and nine years, or in prekindergarten to third grade, children use of letters to represent speech sounds (Bissex, 1980; Gentry, 1981; Henderson, 1989), mostly consonants. The Phonetic Spelling Stage, occurs between the ages of six and twelve years, or in first to seventh grade, children start to use and make phonological judgments about words and use sound-segmentation and articulatory feedback to spell and "inventive spelling" (Beers, 1980; Read, 1986; Treiman, 1993). Vowel spellings and consonants are derived from the letter names ('em' for /m/). Children represent long vowels with the closest letter name, use 'r' to represent r-controlled vowels, and represent all phonemes in words (Ehri, 1986). Finally, in the Morphemic Stage, between the ages of eight and eighteen, or third grade to high school, is characterized by the learning of inflections and morphological endings (–ing, -ed, plural – s), long vowel patterns in multisyllabic words (syntax), the use of V-C-e patterns, use of high frequency letter patterns (e.g., -at, -ight), correct inflectional endings, and a vowel in every syllable, and a schwa in unstressed syllables (Bear, 1992; Ehri, 1986; Frith, 1985). Finally in the derivational constancy stage children master the spelling of two and three syllable words, root words in terms of meaning, and assimilated prefixes characterized by doubled consonants (e.g., i**rr**elevant) Henderson, 1990; Henderson & Templeton, 1986; Templeton & Bear, 1992; Templeton & Scarborough-Franks, 1985; Young, 2007).

Young (2007) conducted research with preschool children in Australia in order to determine if the spelling stages were appropriate and as comprehensive as reported. The children's spelling was above the pre-phonetic stage and they were verbally expressive. Young (2007) used the Ganske (1993) screening and feature inventory and the analysis of five written samples using the Bear, Invernizzi, Templeton, and Johnson (1996) checklist to determine each child's stage of spelling development. The stage of spelling development was determined by the percentage of total correct elements and correctly spelled words. Consistency of spelling performance was measured using editing activities for researcher-created passages and word sorting activities and word writing activities. Spelling results included all six of the children performing within their initially designated stage and consistently across tasks (i.e., in context, single words). One conclusion of this study (Young, 2007) included the need for greater emphasis to be placed on careful assessment of the child's developmental spelling stage by analyzing both correct and incorrectly spelled items to determine if there were developmental errors or patterns among the responses. Another conclusion reached by Young (2007) was the idea that grouping the children in a classroom by developmental stage would benefit the children because focused instruction could be used to increase proficiency and aid in progress of each child to his next developmental stage. Educating each child about the spelling skills that are expected to be mastered in each stage may also help them be more successful.

Overall, the development of functional literacy skills is supported by many researchers with differing viewpoints, who agree that successful decoding and spelling skills need to have a solid foundation – sound-letter correspondence – which supports development of higher level skills. There are many external (environmental) and internal (genetic factors) that can either facilitate development or negatively affect the development of both decoding and written spelling abilities.

Experience with letters and words during shared reading activities, sources of print in the home, school, and immediate environment, and availability of writing instruments (e.g., crayons, pencils, markers) and writing surfaces may affect the child's pre-spelling skills. Additionally, the type of spelling instruction the child receives prior to school, in preschool and elementary school may also affect spelling performance (e.g., phonics, sight words, and whole language). Moats (2005) reported more than 50% of words in the English language are decodable and have a one-to-one sound letter correspondence, while the other 40-45% of words in English are not phonologically decodable (i.e., sight words). If a child has difficulty with phonemic awareness, manipulating the sounds/letters in words, and decoding words he is at risk for spelling difficulties (Hall-Mills & Apel, 2011; Moats, 1985). Children need to learn how to correctly produce letters in order to spell and write words in sentences and paragraphs during all stages of life. Written development has not been researched as often as either decoding/reading or oral spelling (Dockerell & Connelly, 2009).

Spelling development also includes written language development because the process of spelling involves a combination of the fine motor development for letter formation and phoneme-grapheme knowledge to write the correct letter. Children will learn sound-symbol relationships for sounds they are able to orally produce and through all experiences with print (e.g., signs, books, television). Written spelling skills such as print and cursive writing develop along with the decoding stages, and oral spelling stages. Berninger et al. (2002) reported decoding exerted a consistently significant direct influence on handwriting and spelling in typically developing writers from first to sixth grade. Therefore, the ability to correctly decode words may facilitate writing them correctly which strengthens the probability that children will learn to represent letter forms correctly in memory (e.g., words with silent letters and sight-words) and develop routines for the automatic retrieval from memory during reading and spelling activities (Berninger et al., 2002; Berninger et al., 1998; Berninger & Vaughn et al., 1998).

Motor development and written language development data includes age ranges paired with written skills. Early writing development (1-3 years of age) is characterized by imitation or writing/drawing of vertical (|) and horizontal (-) lines. The initial lines develop into independently drawn circles (O) and intersecting lines (+) between the ages of three and four years. Children between the ages of four and six years will learn to copy basic lines and shapes (X,Δ, □) that become actual letters such as capital "X" and "A" (Case-Smith, 1993; Gesell et al., 1940). Children have been observed to progress from writing/scribbling swirls to writing one letter to represent a word, sentence, or phrase (Gentry, 1982; Read, 1971). The child uses symbols (letters) without having any letter-sound correspondences and may not know or be able to identify all of the letters in the alphabet or the conventions of writing left to right (Gentry, 1982; Read, 1971). Children who have attended preschool will develop their writing skills (between the ages of four and six years) including how to form letters, print their names, and use invented spelling in connection with pictures. Most children who have experience with print in their homes will begin to experiment with writing without focused instruction (Moats, 1985). Children from high print homes, with access to and experience with books and joint book reading experience, may go through a stage of logographic reading development sooner than children with little experience with print (Kamhi & Catts, 2005; West, 2003).

School-aged writing continues to develop with formal instruction from single letters to words with clear spacing (ages 6-7), increased legibility (ages 8-9), to the use of clear print and cursive (ages 9-10) for words and sentences (Case-Smith, 1993; Gesell et al., 1940). Motor patterns for handwriting are well established by the fourth grade (ages 10-11 years) (Bourassa & Treiman, 2003). As the child's writing develops and is guided by his caregivers, the child learns about the sound-symbol relationship between sounds/words spoken by the caregiver and the letters on the pages of books and with common signs in the environment (e.g., STOP 

). If a child does not have a good sound-symbol representation, more difficulty will be encountered in writing the letters for each sound that is present in the target word. Therefore, the child's initial spelling proficiency is dependent on the child's oral language production, phonemic and phonological awareness, and orthographic knowledge.

Initially, beginning spellers have difficulty in spelling vowels compared to consonants (Pennington et al. 1986; Schlagal, 1992) for two reasons, auditory discrimination and orthographic inconsistencies. First, Ehri (1987) reported short vowels are more difficult to auditorily discriminate and associate with letters and long vowels are difficult to remember orthographically (Schlagal, 1992) resulting in poor vowel spelling until the fourth grade. Second, the use of the same letter to represent both short and long vowels (e.g., “a” can be used to represent /æ/ in “apple, /a/ in “father”, /ei/ in “age”) may cause difficulty. Long vowels may also be orthographically represented by one letter or a combination of letters (e.g., long e /i/ can be written using “e” in he, “ee” in see, “ei” in receipt, “ea” in hear, “ie” in piece).

Another area of spelling difficulty is the deletion of one consonant in consonant blends (e.g., /m/ vs. /mp/) which are mastered later than single consonants (Treiman, 1993). Additional errors include the omission of liquids (/l/, /r/) and nasals (/n/, /m/, /ŋ/) from consonant blends account for most of the errors through sixth grade (Hoffman & Norris, 1989; Schlagal, 1986, 1989; Sterling, 1983). These spelling errors are similar to articulation errors that have been reported for children with speech sound disorders (Lewis et al., 2011).

The dynamic connections and relationships between oral language, reading, and written language development are very important to all children and adults that are learning to communicate effectively in all three domains. As reading, spelling, and writing develop, neurological pathways are formed between discrete areas in the occipital lobe (visual processing), the language centers of the left hemisphere (angular gyrus, Wernicke’s area), and Broca’s area), and the motor programming area (premotor cortex) (Hynd & Hynd, 1984; Levy, et al., 2009; Norton et al., 2007; Schulte-Körne, 2010). These areas need to be in contact with each other in order for fluent decoding and spelling to occur.

Neurological Correlates of Reading and Spelling

Hynd and Hynd (1984) provided a neurolinguistic model for normal decoding. Pre-reading stages are dependent on the perception of auditory (speech sounds) and visual (letters). Auditory perception and processing of words occur in the Temporal lobe (Heschl's gyrus and Wernicke's area), while perception and processing of visual stimuli occurs in the Occipital Lobe. The left occipital lobe is responsible for perception and integration of strings of letters and words and specialized in abstract and function words. The right occipital lobe is responsible for perceiving and processing concrete words. Next, the angular gyrus in the left hemisphere coordinates the analysis of letters and words. Wernicke's area located in the left and right temporal lobes aids in whole word recognition. In contrast, Broca's area aids in phonetic analysis of words. Finally, word production in oral reading is dependent on the function of the motor strip in the Frontal Lobe which is responsible for composing and executing coordinated movements of the structures of the vocal tract.

The lateralization of language function was first investigated and reported by Paul Broca (1861) and Carl Wernicke (1876). Wernicke (1876) reported that the motor component of language (the images of speech movements) was localized in a frontal region (Broca's area) and that the sensory component of language (auditory images of words) was localized in the posterior part of the superior temporal gyrus (later termed Wernicke's area) (Catani & ffytche, 2005). Differences in the density of the arcuate fasciculus, the pathway between Wernicke's Area and Broca's Area have been reported in relation to dyslexia (Paulesu, Frith, Snowling Gallagher, Morton, & Frackowiak, 1996). Left hemisphere dominance for language function was reported for right-handed participants by Springer et al. (1999) 94% and 96% by Pujol et al. (1999) using functional magnetic resonance imaging (fMRI) technology. These findings are consistent with research for people who were normal prior to stroke (Geshwind, 1970) and epilepsy patients with no report of early brain injuries (see Rasmussen & Milner, 1977). In contrast, Pujol et al. (1999) reported greater atypical (bilateral and right hemisphere) dominance in left-handed subjects and patients with early left hemisphere lesions (Adcock et al., 2003; Rasmussen & Milner, 1977; Springer et al., 1999). There is limited research that is focused on the differences between the language skills for left-handed and right-handed participants; most research has used primarily right-handed participants.

Language-based abilities in decoding, spelling, and writing are processed primarily in the left hemisphere for 90% of the population who are right hand dominant. Auditory processing of phonemes and single words appears to be mediated in large part by both left and right temporal cortex, although some indications of lateralization may be apparent (Peelle, 2012). Processing of real words involves more left hemisphere activity compared to pseudowords which involves some right hemisphere activity (Davis and Gaskell, 2009). The difference between the word types (real, pseudowords) is found because real words are stored with a meaning in the left hemisphere, and the pseudowords do not have a stored meaning or conceptual information resulting in more activity in the right hemisphere (Gagnepain, Henson, & Davis, 2012). Booth and colleagues (2007) reported that left hemisphere neural correlates for 9- to 15-year olds when presented with an auditory spelling task. Results indicated a differentiated activation of the left inferior frontal gyrus when the paired stimuli had different orthographic patterns (increased activity) compared to the phonological representation (e.g., *jazz – has*). In this study (Booth et al., 2007), left hemisphere dominance was observed in asymmetry between the hemispheres in areas used for perception, processing, and production of speech, language, reading and writing.

Gender-related differences have been characterized by better performance by girls on reading and writing tasks (American Association of Women Educational Foundation (AAUW), 1992; Kena, Aud, Johnson, Wang, Zhang, Rathbun, et al., 2014; National Assessment of Educational Progress, 1992). The National Assessment of Educational Progress (1992) reported other data indicated that girls were less likely than boys to get lower grades, be retained, drop out, suffer from learning disabilities, and become involved in drugs, alcohol and crime (AAUW, 1992). The National Center for Education Statistics (2004, 2006) reported gender differences in reading achievement for fourth grade, eighth grade, and twelfth grade students with girls consistently performed better (on average) than boys in reading and writing achievement in 1998, 2002 (Freeman, 2004), and 2005. Performance differences were related to environmental factors such as educational structure, teacher instruction, motivation for reading, and type of reading tasks presented (Educational Alliance, 2007).

Cognitive and neurological performance research has been done for spelling related tasks (Frith, 1980; Masterson & Apel, 2006; Treiman & Bourassa, 2000). Schulte-Körne (2010) reported neurological and genetic factors that affect reading and spelling ability using functional magnetic resonance imaging (fMRI technology).

Converging evidence indicates three important systems in reading, are located primarily in the left hemisphere:(1) Anterior system in the left inferior frontal region (all words); (2) Dorsal parietotemporal system involving angular gyrus, supramarginal gyrus, and posterior portions of the superior temporal gyrus (Phonological/Nonsense words); (3) Ventral occipitotemporal system involving portions of the middle temporal gyrus and middle occipital gyrus (Nonphonological real words). There are also connections between the hemispheres via the splenium that is the rear portion of the corpus callosum, which aid in the processing of visual and auditory stimuli (Figure 4: Henk, 1991; Hynd & Hynd, 1984).

Neurological processing and decoding of different word types have also been investigated using function magnetic resonance imaging (fMRI) (Fiez, Balota, Raichle, & Petersen, 1999; Jobard, Crivello, & Tzourio-Mazoyer, 2003). Norton and colleagues (2007) investigated performance of participants on a spelling decision task for orthographically regular real words and nonwords, and irregular real words and nonwords. Results included the following activation patterns: 1. all word activated the Occipital lobes. 2. Regular words and nonwords activated the left posterior superior temporal gyrus, the right precentral gyrus, and the right fusiform gyrus. 3. Irregular words/sight words activated the left inferior frontal gyrus, left medial temporal gyrus, left medial gyrus, and the right superior temporal gyrus. Richards et al. (2009) provided information from a written spelling task which included the additional activation of the left precentral gyrus and left postcentral gyrus (Richards et al., 2009).

Left Hemisphere **Right Hemisphere**

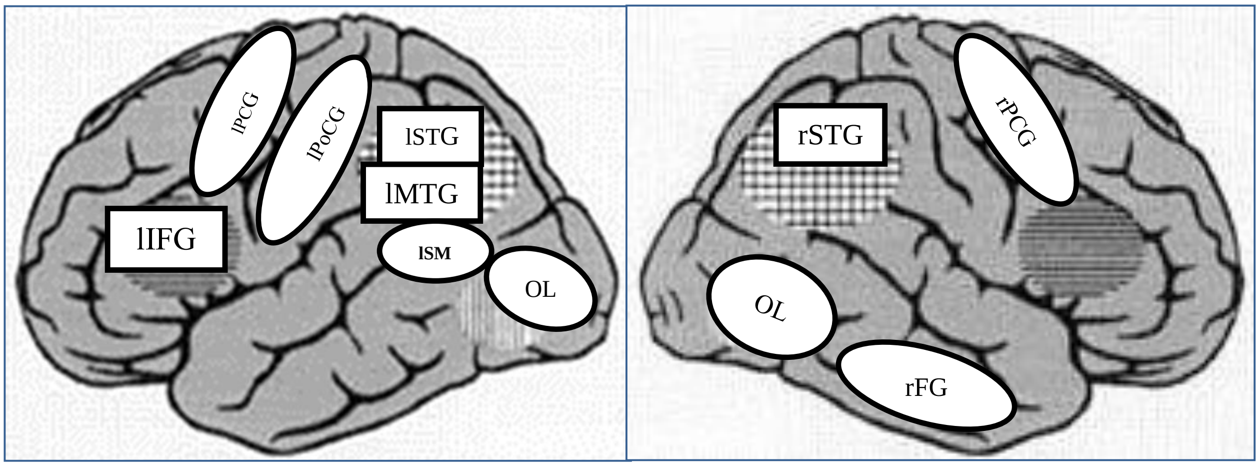

Figure 4: Side Views of Brain Areas Important for Reading and Spelling

Levy et al. (2009) provided investigated the primary and secondary neurological connections and the strengths of those connections during word reading tasks. Decoding connections for word reading involves significant connectivity between the left middle occipital gyrus (L-MOG) to the left occipito-temporal junction (LOT) and the left parietal cortex (LP) and less significant connectivity with the left inferior frontal gyrus (L-IFG) from the LOT to the L-IFG and the LP to the L-IFG. Pseudoword decoding involves significant connectivity between the L-MOG to the LOT, LOT to the LP, and LP to the L-IFG, and less significant connectivity between the LOT and L-IFG. Decoding nonwords involves significant connectivity between the L-MOG and the LOT, the LOT to the LP and less significant connectivity between the L-MOG and LP, LOT to L-IFG and LP to L-IFG. These results support the shared component dual-route model because different strengths of connections were found between neural areas as responses to different types of orthographic stimuli (Levy et al., 2009).

The shared components dual-route model (SCDRM) is the leading theory used to explain the processes and neurolinguistic connections that may differ resulting in different profiles of decoding and spelling abilities, dependent on different stimuli (e.g., word type and orthographic type) (Rapcsak et al., 2007). There is a need for the use of a set of research-based assessment tools to provide support for differential diagnosis of decoding and spelling abilities, and determination of appropriate intervention for the area(s) that are deficient. There is limited research investigating written spelling task performance using the same stimulus words that are used in a decoding/reading task.

Reading Impairments

The International Dyslexia Association (2002) defines dyslexia as specific learning disabilities that are neurological in origin, and characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Secondary consequences of a primary reading impairment may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge (Council on Scientific Affairs, 1989; Shaywitz, 1998; Shaywitz & Shaywitz, 2003; Vellutino, Fletcher, Snowling, & Scanlon, 2004). The terms “specific reading disability,” “reading disability,” “reading disorder,” “reading impairment,” and “dyslexia” are often used interchangeably in the literature (Vellutino et al., 2004), this study will use the term “reading impairment” to represent a deficit in either phonological or sight-word decoding.

Prevalence of Reading impairments/Dyslexia

Approximately 80% of people with learning disabilities have reading impairments (dyslexia), which makes it the most common learning disability (Lyon, 1996, 1997, 1998; Shaywitz, 1998; Shaywitz & Shaywitz, 2007; Torgeson, 1998). The prevalence of reading disability is approximately 5% to 20% of school-aged children in the United States depending on the definition chosen (Shaywitz, 1998; Shaywitz, 2003; Shaywitz, Escobar, Shaywitz, Fletcher, & Makuch, 1992; Shaywitz & Shaywitz, 2007;Shaywitz, Shaywitz, Fletcher, & Escobar, 1990) There are four prominent theories that address the causes of reading impairments: the phonological core theory (Torgeson, Stanovich, Gough, & Tunmer, 1994), temporal processing deficit (Tallal, 1980), speed of processing deficit (Breznitz & Berman, 2003), and the double deficit hypothesis (Wolf & Bowers, 1999).

Theories of Reading impairments

The phonological core theory (Torgeson, et al., 1994) posits in order to be successful in decoding words and sentences while reading, there must be proficiency in four sublevels of phonological processing skills: phonological awareness, phonological memory, phonological retrieval, and phonological production (Catts & Kamhi, 2005; Stanovich, 1994; Torgeson et al., 1994).

Phonological awareness is a general level of awareness which includes phonemic awareness, the ability to reflect on and manipulate phonemic segments of speech. Phonemic awareness contributes significantly to the development of word reading and word decoding skills, by aiding children in learning the alphabetic principle, learning that there is a grapheme-phoneme relationship, and using this knowledge to decode both familiar and unfamiliar words (Catts & Kamhi, 2005). Phonological awareness provides individuals with the ability to break words into syllables, and component phonemes, to synthesize words from discrete sounds, and to learn about the distinctive features of words (Torgeson & Wagner, 1998). Deficits in the phonemic and phonological awareness will affect the individual's decoding and reading skills and phonological memory. Finally, phonological memory involves coding information phonologically for temporary storage in working or short-term memory. Phonological short-term memory involves storing distinct phonological for short periods of time to be used in the process of applying the alphabetic principle to word identification (Wagner, Torgeson, & Rashotte, 1999). Researchers have tested phonological memory using nonword repetition tasks (Gathercole & Baddeley, 1990). Individuals with poor phonemic or phonological awareness skills who are not able to segment and synthesize words may not be able to store the correct information in short-term memory and have trouble with retrieval of words needed during reading.

Temporal processing deficit

The relationship between temporal processing deficits and reading impairments has been investigated for more than 30 years. Hirsh (1959) proposed that deficits in auditory sequencing and auditory memory are dependent on basic auditory abilities known as auditory temporal resolution and auditory discrimination. The ability to perceive and integrate auditory information, specifically speech sounds, is necessary for successful communication, and may have implications in the area of reading impairments.

Tallal (1980) conducted research into the presence of temporal processing deficits focused on the perception and processing of basic auditory stimuli including speech signals. Speaking is a transparent and fast-paced form of communication and as a result, a deficit in the basic perception of speech sounds may affect receptive and expressive oral language skills, reading, and writing skills. Researchers have reported that infants with deficits in the temporal processing abilities may have speech and language impairments, and reading and writing difficulties in the future (Jusczyk, Luce, & Charles-Luce, 1994; Trehub & Henderson 1996).

Tallal (1980) reported poor readers between the ages of 9 and 12 years had deficits in perceptual judgment of rapidly presented non-speech stimuli and that their performance reading nonsense words was closely related to phonological decoding skills but not sight word decoding. The focus of this line of research was to determine the underlying neurological processes that may account for the presence of reading impairments. This is an added refinement that may provide additional explanation of phonological processing abilities and deficits.

Speed of Processing

Breznitz and Berman (2003) reported the speed of processing of linguistic and nonlinguistic stimuli was related to the complexity of the task, the modality, and the stage of processing for both children with dyslexia and normal children. At the lower level (perceptual) the speed of processing of nonlinguistic visual (light flashes) and auditory information (beeps) was faster compared to linguistic stimuli (phonemes and graphemes). Higher order speed of processing (memory processing) at the word level for both nonlinguistic and linguistic information was processed slower, reflecting the need for more time to process auditory-phonological information (nonwords and rhyming words) when compared to visual-orthographic holistic processing (sight words and real words).

Breznitz and Berman (2003) in this study focused on three components: the N100, P200, and P300. The N100 has been related to the initiation of attention (Oades, et al., 1997; Novak, Ritter, & Vaughan, 1992) and arousal (Leppanen & Lyytinen, 1997). Researchers reported that normal reader's responses to visually presented words N100 occurred at 80-180 ms (Nobre & McCarthy, 1995) and auditorily presented words the N100 occurred at 50-120 ms. Therefore, participants began processing auditorily presented words before visually presented words.

Response times recorded during reading/decoding research with children with dyslexia were longer during both simple auditory recognition and visual identification tasks for words that required contextual integration. Children with dyslexia, lacked consistency in all three response signals (N100, P200, P300), leading the researchers to conclude there were multiple factors to consider when evaluating children with language impairments and reading impairments using visually presented words (Neville, Coffey, Holcomb, & Tallal, 1993). When paired with reading/decoding single words and words in context, the presence of a difference in processing visual stimuli (i.e., letters and words) characterized by longer response times compared to auditorily presented stimuli may explain the differences in decoding phonetically decodable words and nonphonetic words (i.e., sight words) for children with reading impairments. In order to reduce the result of word type differences, research was conducted by Breznitz (1988, 1997a), to see if a difference in presentation time of the stimuli decreased the amount of time needed to decode words in print.

Breznitz and colleagues (1992, 1997, and 1998) investigated the effects of presentation time on reading accuracy and comprehension for adults and children with developmental and acquired dyslexia. The "acceleration phenomenon" has been investigated (Breznitz, 1988, 1997a) with children and adults with reading impairments including young readers with attention deficits, developmental dyslexics (Breznitz, 1997a, 1997b), garden variety poor readers (Norman & Breznitz, 1992; Breznitz & Norman, 1998), and acquired dyslexics. Only participants with acquired dyslexia demonstrated worse decoding and comprehension compared with the participants with developmental dyslexia under the accelerated conditions (when stimuli are presented on a computer at a rate faster than the readers' current speed). Overall reading performance for those that responded to the accelerated condition was characterized by fewer hesitations and pauses, increased attention span and reduced distractibility (Breznitz, 1997a).

The three aforementioned theories (phonological core theory, temporal processing, and speed of processing) have a primary focus on the phonological aspect of reading impairments. The fourth theory, the double deficit hypothesis holds phonological processing as an initial factor of reading deficits and rapid automatized naming speed and a secondary factor.

Double deficit hypothesis

Wolf and Bowers (1999) proposed the double deficit hypothesis to explain that deficits in phonological processing and naming speed represent independent sources of dysfunction in dyslexia. The development of this hypothesis stemmed from a narrative review of the literature that identified the existence of a group of individuals with dyslexia who showed adequate decoding skills but poor comprehension and for whom phonological processing as an identification and intervention method was not effective. The double deficit hypothesis of dyslexia categorizes readers according to the presence or absence of two underlying cognitive processes—phonological processing and naming speed—and posits the existence of three subtypes of reading impairment. The phonological-deficit subtype is defined as having a phonological deficit with average naming speed ability resulting in a moderate reading impairment. The naming speed–deficit subtype is defined as having a naming speed deficit in the presence of average phonological skills have the least reading impairment. Finally, the double deficit subtype is defined as having both naming speed and phonological deficits, resulting in the most severe reading impairment (Wolf & Bowers, 1999).

This hypothesis includes the possibility that children with reading impairments may have deficits in more than one area of processing such as attention, memory, lexical, and articulatory processes (Wolf, Bowers, & Biddle, 2000). In 1995, Bower reanalyzed cross-sectional and longitudinal sample of children between kindergarten and fourth grade in the United States and Canada. The *Auditory Analysis Test* (Rosener & Simon, 1971) with a cutoff of the 35^{th} percentile for phonemic awareness and digit naming speed was used to group the children. In 1997, Wolf reanalyzed the sample using a one standard deviation and classified letter or digit-naming speed and phonological nonsense word decoding. Phonological nonsense word decoding is a more reliable measure since ceiling effects appeared at fourth grade on phoneme awareness tests. This research was used as a basis for the double deficit hypothesis that has been used for differential diagnosis of reading impairments.

Wolf and Bowers (1999) presented the Double Deficit Hypothesis based on phonological processing deficits (ability to identify and manipulate sounds in speech) and rapid automatic naming (transformation of visual information such as pictures, objects, and letters into a phonologically-based representation (Denckla & Rudel, 1974). Areas of deficit were compared and contrasted in order to differentially diagnose disorders and obtain areas of strength that could be used for successful intervention. These measures allow for the separation of children into four groups: average group, rate group, phonology group, and double deficit group using naming speed, phonological nonsense word decoding tasks. This double deficit hypothesis provides support for the share-component dual-route model of reading and spelling (Rapcsak, et al., 2007).

In 2002, Wolf et al. (2002) studied the reading skills of second and third graders. Results included more than 60% of second and third grade children had two areas of deficit (double deficit) and 15-20% had deficits in only one area assessed. As a group, children with double deficits often have reading problems that may include deficits in at least two of the following areas: phonological decoding, orthographic processing, and reading fluency. Children in the double deficit group are at greater risk for more severe reading disabilities than children with single deficits (Wolf et al., 2002) because they tend to have more severe problems in each deficit area (phonological decoding, sight-word decoding, orthographic processing, and oral reading fluency), so collectively, there is more cause for concern (Compton, DeFries, & Olson, 2001; Schatschneider, Carlson, Francis, Foorman, & Fletcher, 2002).

Simos (2000) reported adults between the ages of 25-49 years had differences in their ability to decoding 80 monosyllabic four-to-six letter exception words, pseudohomophones, and pseudowords using MRI technology. Each participant was to the stimulus word-form presented as accurately and quickly as possible. Results included significantly slower times for the production of pseudowords for all participants, when compared to real exception words, and pseudohomophones. Additionally, there was activation of different left hemisphere structures for the real words (Medial Temporal Gyrus posterior) and the pseudohomophones and pseudowords (Superior Temporal Gyrus posterior) providing support for the dual-route model (Coltheart et al., 2001).

Primary Reading Impairments (dyslexia) have a neurological basis which may be the result of both genetic factors and affected by environmental influences. Both genetic and environmental influences affect the expression of dyslexia (Shaywitz, 1996). Dyslexia has been identified as having a strong genetic basis (Council on Scientific Affairs, 1989; DeFries, 1996; Lyon, 1996; Pennington, 1999; Shaywitz, 1998; Shaywitz & Shaywitz, 2003; Shaywitz & Shaywitz, 2007; Vellutino et al., 2004). Approximately 40% of siblings, children, or parents of an affected person will have dyslexia, demonstrating that although dyslexia may be inherited, it may also exist in the absence of a family history. Results of family and twin studies have suggested that 50% of the problems in performance can be accounted for by heritable factors; environmental influences are greater in children with lower IQ scores (Rimrodt & Lipkin, 2011).

Reading disabilities seem to affect males slightly more than females, (Berninger, 2008; Flynn & Rahbar, 1994; Rutter, Caspi, Fergusson et al., 2004; Shaywitz, Shaywitz, Fletcher, & Escobar, 1990), although schools tend to identify boys with them twice as often as girls (National Center for Learning Disabilities, 2009; Shaywitz & Shaywitz, 2007). The rate of referral and diagnosis may be skewed in favor of boys with more reading problems for a number of reasons, such as acting out, increased frustration, and not completing in-school and homework activities (Rutter et al. 2004).

Many researchers have found that children with reading impairments and dyslexia have more difficulty pronouncing nonwords compared to reading-level-matched children and good orthographic knowledge (Rack et al., 1992; Siegel et al., 1995; Stanovich et al., 1997). Older children with reading impairments are typically reading-level-matched with younger children without reading impairments. It is possible that the older children with dyslexia have a phonological deficit and have learned to compensate for this deficit using visual or orthographic strategies (Bourassa & Treiman, 2003) allowing them to learn to decode and to spell using their orthographic knowledge.

Spelling Disorders

Spelling performance is typically measured in the overall accuracy. The comparison of spelling errors (e.g., phonetic, phonological, etc.) provides more insight into the spelling ability level of participants (Boder, 1973; Vise, 1992). Poor spellers may have difficulty with remembering letters in words because of trouble noticing, remembering, and recalling features of language represented by letters (IDA, 2008). Additionally, a delay in orthographic knowledge acquisition and may be characterized by word confusion, recall delays/difficulties, problems with memory, and not making normal progress in spelling (Moats, 1985). Bruck (1987) reported that people with Specific Learning Disabilities (SLD) make limited spelling progress into adulthood. There are people who have good reading skills but are poor spellers, while others have deficits in both reading and spelling performance. Foreman and Francis (1994) reported children who have poor spelling may also have deficits on phonological process testing. Some spelling improvement had been noted when focused instruction for the identification of speech sounds in words with blocks (Bradley & Bryant, 1983; Treiman & Baron, 1983). Once children developed phoneme analysis with spelling and are able to spell words phonetically, they are considered "ready to learn to spell." Phonological skill is most important for early spelling development, although visual letter sequence memory is necessary for proficient spelling (Moats, 1985).

Children who are poor spellers have more separateness between phonological and orthographic processing compared to good spellers (Ehri, 1986). Poor spellers remain overly dependent on sound because they cannot retrieve a word image from the orthographic processor compared to good spellers (Ehri, 1986). Many researchers have compared older participants with a diagnosis of dyslexia and poor spelling performance with younger good spellers on structured dictated spelling tasks (Bruck & Waters, 1988; Carlisle, 1987; Moats, 1983; Nelson, 1980; Pennington et al., 1986; Worthy & Invernizzi, 1990). Worthy and Invernizzi (1990) recorded phonological spelling errors of older spelling disabled (SD) and global language disordered (GLD) participants that were similar to errors produced by younger IQ-matched and achievement-level matched participants. In this study, the older SD and GLD participants also had low verbal IQ scores or had not achieved phonemic awareness or phonetic spelling ability. More than 50% of the spelling errors produced by the children with reading and spelling disorders were either phonetically inaccurate, morphemic errors (e.g., -ed, -ing), differences in pronunciation, syllables, end of words, and with increased linguistic complexity. Overall, errors were found on words with inflections that have complex and difficult to identify sound-spelling structures.

Detailed analysis of spelling performance including both accurately spelled items and the spelling errors (e.g., phonetic, phonological, etc.) may provide more insight into the spelling ability level of participants (Boder, 1973; Vise, 1992). Children and adults with spelling deficits had low literacy levels, lower vocabulary scores on standardized tests, and more errors for inflections and deletion of unstressed syllables from multisyllabic words (Boder, 1973; Kibel & Miles, 1994; Vise, 1992) when compared to good readers. Kibel & Miles (1994) reported older participants in their research had comorbid underdeveloped phonological abilities resulting in primarily phonological errors, errors in voiced/unvoiced sounds, and omission of the second letter of a consonant cluster. Fry (1995) reported spelling errors included homophones (e.g., their/there, your/you’re, to/too) and misspelled words that contained missing post-vocalic sonorants (i.e., l, r, m, n). These results support the need to use more than a generic category of reading impairments or spelling disorders by comparing and contrasting the decoding and spelling differences to subtyping and grouping children based on their reading and spelling strengths and weakness to guide direct focused instruction and intervention as proposed by Boder (1973) and Wolfe & Bowers (1999).

Richardson (1999) reported many children with decoding and/or spelling deficits have comorbid written language deficits (dysgraphia), which also affects academic performance. Writing is present in all academic subjects in a variety of tasks such as note taking, in class and homework assignments, and research.

Subtyping Reading and Spelling Disorders

Traditionally, reading and spelling disorders are assessed and diagnosed separately; this is not beneficial since reading and spelling are strongly interdependent. Oral language competence has been reflected in reading and writing skills (Horowitz & Samuels, 1987; Olson, Torrance & Hildyard, 1985) linking oral language disorders with specific reading disabilities. Many children with reading and spelling deficits typically have a history of receiving speech and/or language therapy. Researchers have provided results that support the presence of speech-sound disorders has affected phonemic and phonological awareness development (e.g., Ganske, 1999); while others have determined that presence of limited experience with reading and practice with written spelling (e.g., Berninger et al., 2009).

Boder (1973) proposed three subtypes of decoding deficits: the dysphonetic, dyseidetic, and dysphonetic-dyseidetic (mixed) based on the results obtained in her research. The dysphonetic subtype is characterized by poor phonological decoding and good sight word decoding; the dyseidetic subtype is characterized by poor sight word reading, and intact phonological decoding; finally, the dysphonetic-dyseidetic (mixed) subtype is characterized by poor phonological and sight word reading.

Boder (1973) reported the spelling performance for her participants because decoding and spelling abilities are interrelated. First, children with a dyphonetic decoding deficit had intact sight word spelling with poor phonetic spelling. Second, children with a dyseidetic decoding deficit had intact phonetic spelling skills and attempted to spell sight words phonetically. Finally, children with a mixed dysphonetic-dyseidetic decoding deficit had difficulty spelling both phonetic and nonphonetic words. Subtyping reading and spelling deficits is important for providing the proper diagnostic information to use to determine intervention strategies (Boder & Jarrico, 1982).

Poor spellers may have difficulty with remembering letters in words because of trouble noticing, remembering, and recalling features of language represented by letters (IDA, 2008). In transparent languages, such as German and Italian, spelling disorder is characterized by a significantly increased number of spelling errors. In English, a deeply orthographic language, more rule-based and nonphonetic errors are present in the writing of children with spelling disorders. Children with spelling disorders usually correctly spell only 10% of the words in a writing-to-dictation task (Schulte-Körne, 2010).

Spelling disorders are comorbid with reading impairments (dyslexia) and writing deficits (Bruck & Treiman, 1990; Case-Smith, 1993). Snowling (1985) reported that reading and spelling development occur out of phase of each other, so there is a possibility for a child to perform at one stage of decoding, and a similar or different stage of spelling. Elena Boder (1973) proposed the use of a profile that included one of 4 subtypes of reading: normal and three subtypes of reading impairments/dyslexia based on the types of errors recorded during single word decoding tasks and a written spelling task. The *Boder Test of Reading and Spelling* (Boder & Jarrico, 1982) contains single word stimuli that are both phonologically decodable and not phonologically decodable, to determine the decoding accuracy and spelling accuracy for participants from preschool age to adults. Participants were required to read words accurately and quickly and then spell (write) them for the *Boder Test of Reading and Spelling* (Boder & Jarrico, 1982). Measures of accuracy were collected in two conditions: 1. Flash: within 1 second gives a measure of sight-word vocabulary. Second, words that were not correctly produced in 1 second are reviewed and the accuracy is recorded. Finally, five words from the Flash column and five words from the Nonresponse column were used for the Spelling test. The accuracy of the words spelled was scored in addition a review of the types of spelling errors. Both correct and incorrect responses were calculated and used to compile a reading-spelling profile for each participant. Unfortunately, the *Boder Test of Reading and Spelling* is not available (out of print) and subtyping of both decoding and spelling is not typically done for every child that is not successful in school or referred for an evaluation which limits diagnostic information that is available to the speech-language pathologist for differential diagnosis and development of a client-specific intervention program.

Bourassa and Treiman (1990) reported children with poor spelling skills had rule-based errors such as leaving out the vowel in a consonant-vowel-consonant (CVC) words (e.g., cr for car), additional of a final ‘e’ with a short vowel sound (e.g., halfe for half), omission of the second consonant in a consonant blend (e.g., tip for trip), and omission of initial consonants in clusters (Bruck & Treiman, 1990). Deacon et al. (2011) reported children with diagnosed reading impairments had more difficulty spelling and writing words that required doubling of consonants before adding suffixes (e.g., jog = jogger) and words that differed in vowel length (e.g., skate = skater) by using single consonants more often than children without reading impairments (e.g., jog ≠ jogger). Deacon et al. (2011) did not report any details such as the assessment measures used to determine reading impairments, so no comparison of decoding and spelling errors could be performed.

Parameters in Reading and Spelling

Researchers have used a variety of stimuli to obtain decoding and spelling accuracy data in English and other languages (e.g., Boder, 1973; DeLuca, Barca, Burani, Zoccolotti, 2008; DiFilippo, DeLuca, Judica, Spinelli, & Zoccolotti, 2006; Leach et al., 2003; New et al., 2006; Spinelli et al., 2005; Young, 2007). Independent research variables have included single syllable real and nonsense words presented in isolation, sentences, and in context. Dependent variables have included one or more of the following: response accuracy (whether the word is correctly said or not) and response latency times (milliseconds), and lexical decision accuracy (is the word real or not) and response latency times (ms). The reading impairment group participants typically have lower decoding accuracy, longer average response latency (in milliseconds), and lower lexical decision accuracy and response latency times for real words that are unfamiliar (low frequency) and pseudowords (nonsense words) compared to high frequency real words for both typically developing readers. The accuracy and response latency differences as a function of word type have also been investigated.

Word Types

Real words and Nonsense words. Real words may be obtained from grade level sight word lists, grade level spelling lists, and standardized test instruments such as the *Wide Range Achievement Test-Revised* (*WRAT-R;* Wilkinson & Robertson, 2006), *Woodcock Reading Mastery Test-Revised* (WRMT-R; Woodcock, 1987) for research and assessment. In contrast, nonsense words are typically different from real words by only one letter, which increases the similarity, and gives the nonword a grammatical neighbor for all lengths, which would skew the results. Ferrand and colleagues (2000, 2003) reported reaction times (RT) for nonwords increased almost linearly from 723 milliseconds (ms) for 3-letter nonwords to 1,003 ms for 13-letter nonwords with multisyllabic words. Ferrand and New (2003) used low-frequency multisyllabic words and results included a syllable length effect that was controlled for number of letters, number of neighbors, bigram frequency, initial phoneme, and initial syllable. A syllable effect was found to be independent of frequency, number of letters, and number of orthographic neighbors. These English results were similar to the results found in lexical naming and lexical decision tasks in French (Ferrand, 2000; Ferrand & New, 2003). There are multiple word frequency lists that have been composed using either children's literature (Dolch, 1936; Fry, 2000; Thorndike and Lorge, 1944; Zeno, Ivens, Millard, & Duvvuri, 1995) or adult literature (Kučera and Francis, 1967) to determine if words are high frequency or low frequency, which has not helped with generalizability of research results. There are different limitations for the word lists, Dolch (1936) used words that would be read by children in Kindergarten to second grades, Fry (2000) used words that would be read by children from third grade to high school. Another limitation for the word lists includes the number of syllables in the words, a majority of the words on the Dolch word lists (1936) are monosyllabic and disyllabic, the Fry (2000) list has more multisyllabic words. A majority of the real words used in this study were chosen from the Dolch word lists (Dolch, 1936) and the Fry list (2000) which contain one and two syllable words. Longer words, with three, four, and five syllables were adapted from a fourth grade spelling list (Perkins, 2013). The 50 real word stimuli were analyzed by two databases made available by Bååth (Childfreq; 2010) and Davies (Word Frequency Data, 2010), to determine the word frequency for the real words used in this study, and control for possible word frequency effects (see Appendix C). There were differences in the frequency measures for this study because of the number of words that are present in the database which are based on the sources used for the words. The Childfreq database (Bååth, 2010) classified 13 phonetic words as low frequency (< 50 uses) and 14 nonphonetic as low frequency for children who are younger than 9 years of age. In contrast, there were only 4 phonetic words that were classified as low frequency (not in the 5,000 word database) by the Davies (2010) database. Specifically, there was a listing for the word "lane" within the Davies Word Frequency Data (2010) database (# 4177 of 5000); however, there was not a listing for "lame" the word that was used in this study in either the Childfreq (Bååth, 2010) or Davies (2010) databases, so it was classified as low frequency. Another variable that has affected response accuracy and response latency times is word length.

Word Length

Word length is one of the key diagnostic lexical variables to affect response latencies in visual word recognition. Word length is measured in either number of letters or number of syllables. A considerable number of studies have examined word-length effects, either by using naming tasks or lexical decision tasks (Balota, Cortese, Sergent-Marshall, Spieler, & Yap, 2004; Forster & Chambers, 1973; Frederiksen & Kroll, 1976; New et al., 2006; Nazir et al., 2004; Weekes, 1997; Whaley, 1978).

Nazir et al. (2004) investigated the possible effects of word length (number of letters and syllables) on rate and accuracy of decoding words and nonwords for Italian adult readers using words from the English Lexicon Project (Balota et al., 2007). The Italian speaker results also included a U-shaped curve for the rate and accuracy of decoding words with increased number of letter and syllables using a database of words in English in the English Lexicon Project which was not expected (New et al., 2006, Figure 5). Conclusions included words of 6-9 letters have the best chance of being processed with only one fixation of the eyes and in less time compared to shorter words that are typically skipped and longer words (more than 9 letters) required more than one fixation of the eyes while reading resulting in longer response times (Nazir et al., 2004). Fifty-five percent (55%) of the stimulus words in the reading passage that were analyzed were between 5-8 letters (New et al., 2006) and had shorter response times compared to shorter (< 5 letters) and longer words (> 9 letters). These results can be related to decoding performance for words in both single word lists and words in context that contain different word lengths that are encountered in daily reading activities. Children with reading impairments typically have more difficulty with longer words characterized by longer decoding response times for single words and during contextual oral reading activities.

Spinelli and colleagues (2005) also reported results from a study that used a word naming task in Italian with an increase in reading time with an increase in the number of letters and syllables for words up to 3-8 letters, and a difference for words that were longer than 8 letters. Readers with dyslexia (determined by results of < 1.5 standard deviations on the Reading subtest and > 22 percentile on *Raven's Progressive Matrices*) had longer reaction times (from presentation of the word to vocalization) for all lengths of words (range from ~850 to 1500 ms). There was an effect of word length and significant increase between 5-6 letters and 6-7 letters, but not 7-8 letters for proficient readers. There was a dramatic increase in reaction time (RT) with increasing word length (slope = 142) for the dyslexic readers. There were significant group (proficient and dyslexic) effect and word length 3-8 letters effect and interaction for sixth and seventh graders. Proficient readers showed no significant difference for 3, 4, 5, 6 letters, or 7-8 letter comparisons, but difference between 6-7 letter words. There was a significant increase in RT for 3-4, 4-5, 5-6, and 6-7 letter words, but not for 7-8 letters, for the Dyslexic group. Dyslexic readers were split into two groups based on the linear regression model 48% fit in the model and showed an increase in RT with increase in word length (Type B) with a slope of 199 ms; 52% (Type A) had a plateau of RT for 2-4 letter words followed by and increase with a smaller slope (126 ms) than Type B for words with 4 letters up to 8 letters. Similar word length results were reported by Spinelli and colleagues (2005).

Spinelli et al. (2005) reported the use of a sequential decoding pattern by the dyslexic children in sixth and seventh grade, which resulted in a slower naming and large word length effect with a linear slope of 142 ms per grapheme. In English (Seymour & MacGregor, 1984), reported a marked word-length effect for only morphemic dyslexics with a linear slope of 200 ms per letter), which was similar to the Type B dyslexics in Spinelli et al. (2005). Therefore, "it can be posited that a large word length effect in dyslexia is more common in transparent languages such as Italian than in English."

New et al. (2006) investigated the effects of word length on naming latency for 40,481 English monosyllabic and disyllabic words in the English Lexicon Project (Balota et al., 2007) for 444 college-aged students from six American universities. New et al. (2006) reviewed prior decoding/reading literature in a meta-analysis and found that a majority of the stimuli used for research were monosyllabic words and reaction times in single word decoding scenarios were limited and result included a lot of variability. Overall, there was an increase in the response time with increased word length, but there were not controls for word frequency or number of word neighbors, which may have affected results.

New et al. (2006) performed multiple regression analyses with all predictors: number of syllables, number of neighbors, and word frequency for 33,006 words with the dependent variable of raw reaction times in a lexical decision task in order to investigate this linear increase in reaction times. Results included: a moderate positive correlation for a reaction time increase with a word length increase ($r = .51$, $p < .001$) and a moderate negative correlation ($r = -.63$, $p = < .001$) for number of letters and number of neighbors and strong positive correlation ($r = .81$, $p = < .001$) for number of letter and number of syllables. This longer response time would be expected because longer words are harder to recognize and require additional decoding time. The overall regression equation was significant and the model accounted for 53% of variance. Third, multiple regression analysis was conducted on word length pairs for 3-13 letters. In contrast to expectations, results showed that frequency, number of neighbors, number of syllables all made consistent contributions throughout the range of lengths. This means the effect of word length on the relationship between lexical decision times and word lengths is a U-shaped distribution with longer times for short 3-5 letters (facilitory) and long words (inhibitory) compared to words between 5-8 letters in length (null). Fourth, results of multiple regression on the nouns (3,833 words that were not inflected, morphologically complex, or stimuli that fit into more than one grammatical category) were 3-10 letters long included frequency and number of syllables were significant contributors throughout the lengths, and the word length effect had the same U-shaped curve. Finally, multiple regression analysis was used while controlling for number of syllables included 12,987 bisyllabic words. The same U-shaped curve was still found and was not the result of the difference in the number of syllables. Overall, the length effect was independent of frequency, number of syllables, and number of orthographic neighbors. This U-shaped response time curve which is characterized by longer response times for words between 3-5 letters, shorter response times for words between 5-8 letters, and longer response times for words longer than letters, as opposed to a positive linear response time line characterized by an increase in response time with an increase in word length, could also be the cause of the mixed results. Balota et al. (2004) reported inhibitory effects for single-syllable English high-frequency words and low-frequency words.

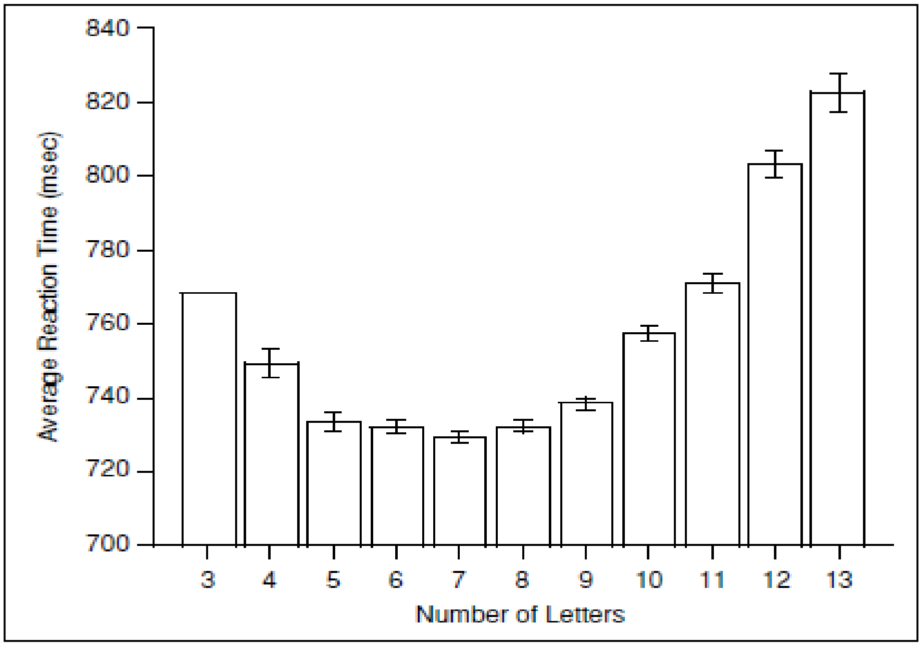

Figure 5: Average Reaction Times for Words between 3-13 Letters (New et al., 2006)

Leach, Scarborough, and Rescorla (2003) reported that there is a lot of variability of reading/decoding profiles based on reading abilities of children younger than the age of nine years. In an investigation of reading ability of fourth and fifth graders, Leach et al. (2003) found that thirty-three percent (33%) of the children had little or no difficulty with decoding rate and/or accuracy, reading comprehension, and spelling accuracy, which left sixty-seven percent (67%) of children with different profiles that contain decoding and/or spelling deficits. Subtyping of deficits for the children with decoding deficits included only word-level deficits (42%), or a combination of decoding and reading comprehension deficits (39%), or only reading comprehension (18%) deficits. Leach et al. (2003) conducted this investigation because there was a paucity of research that has investigated the reading and spelling skills or included children in the fourth grade and older (Stanovich, 2005).

Research Differences

There continues to be a paucity of research that has investigated both reading and spelling abilities using the same stimuli and participants that are similar in age. Variation in the demographics of participants, such as age and gender, and characteristics of the stimuli used in research and assessment has limited the comparison of results and classification of reading and spelling performance. There is a need for additional investigation into the possible impact that age differences and stimulus differences on the reading and spelling skills for children with and without reading impairments.

Age differences of participants. The differences in the classification of decoding abilities may be affected by the experiences and abilities at different ages (Chall, 1983). The use of reading-level matched groups typically results in a difference in chronological age of at least one year with the older children in the experimental reading group and younger children in the control group (Ehri, 1989; Frith, 1980; Griffith, 1991; Tangel & Blachman, 1992, 1995; Uhry & Shepherd, 1993). There are few (if any) longitudinal studies that report both reading and spelling development (Boder, 1973; Caravolas, Hulme, & Snowling, 2001; Maughan et al., 2009). Differences in the reading and spelling experience of children in different grade and age levels may have an impact on the results, which has not been thoroughly investigated. Another experientially related factor in research would be the familiarity with the lexical/word stimuli that are used to measure decoding and spelling ability.

Stimuli differences. Characteristics of assessment and research stimuli, such as word type (real words and nonsense words), orthographic type (phonetic and nonphonetic), and word length (1-5 syllables) may affect the results that are used to make the initial diagnosis of reading impairments and lead to difficulty interpreting the results. Specifically, the single word stimuli of the *Woodcock Reading Mastery Test- Revised* (*WRMT-R,* Woodcock, 1987) and the *Woodcock Reading Mastery Test - III* (*WRMT-III,* Woodcock, 2011) Word Identification and Word Attack subtests contain words that are different in word type (real words and nonsense words respectively), orthographic type (both phonetic and nonphonetic), and word length (1-5 syllables). The Word Identification subtest is designed to measure sight-word reading ability, but it contains words that are phonetically decodable and nonphonetic (true sight words). The Word Attack subtest is designed to measure phonetic decoding skills and also contains phonetically decodable and nonphonetic words. There are real words and nonsense words in both subtests that are phonetically decodable (e.g., big, vunhip) and not phonetically decodable (e.g., ache, mieb), however there is not a separate accuracy score for the orthographic subtype, which limits important diagnostic information. Stimulus items in the *WRMT-III* Word Identification and Word Attack subtests are not separated by orthographic type despite the goal of each subtest, which is a major limitation. Differences in the stimuli may affect the client's performance and results are not representative of the client's true decoding abilities.

Researchers have used stimuli have been categorized by one or two of the three categories: word type (real words and nonsense words), orthographic type, and word length (number of syllables). Boder (1973, 1976) provided decoding and spelling research results for real words (word type) that varied in orthographic type (phonetic, nonphonetic) and the *Boder*

Test of Reading and Spelling (Boder & Jarrico, 1982), a screening tool for diagnosing reading and spelling deficits. Additional research has reported a variety of decoding accuracy and response latency effects of word length and word type for one to three syllable real and nonsense words in English, French, and German (Balota et al., 2007; Bonin, Meot, Millottee, & Barry, 2013; Duncan & Seymour, 2003; Leach et al., 2003; New et al., 2006; Spinelli et al., 2005) for different age groups (e.g., child, adult). There is a paucity of research that has reported decoding accuracy results using all three categories: word type, orthographic type, and word length for a group of same-aged participants. Additionally, there is a lack of definitive research that has collected both decoding and spelling data using the same stimuli balanced by word type, orthographic type, and word length.

There is no published assessment tool that measures the decoding skill and spelling skills for children, which limits the gathering of vital information that may be used by speech-language pathologist for diagnosis and treatment. The only test that had been used to evaluate both decoding and spelling using the same stimuli was the *Boder Test of Reading and Spelling (BTRS,* Boder & Jarrico, 1982). The *BTRS* manual suggests that results may be used to differentially diagnose developmental dyslexia from nonspecific reading disabilities. A reading-spelling profile including subtypes (normal, dysphonetic, dyseidetic, or mixed) can be compiled from the results of the *BTRS*. Unfortunately, the *BTRS* is no longer in print or available for purchase, so SLPs are limited because there are no tests that assess both decoding and written spelling.

Currently, researchers and SLPs need to have two different tests, one for decoding and one for written spelling. Unfortunately, there is no guarantee that the stimulus items on the spelling test are similar or different when compared to the stimulus items in the decoding test. The diagnosis of a spelling disorder may be done using one or more standardized tests in research. Standardized spelling assessment tools that have been used to measure spelling abilities such as The *Test of Written Spelling-4* (Larsen, Hammill, & Moats, 1999), the *Wide Range Achievement Test* Spelling subtest (*WRAT-4;* Wilkinson & Robertson, 2006), and state-formulated assessments and teacher-formulated assessments. The *Developmental Spelling Assessment* (Ganske, 1999) requires a child to write a dictated word that is presented in isolation, in context, and then in isolation in order to determine the present spelling level. However, these assessment tools are not used consistently in all schools and countries. The lack of research and assessment tools that use the same stimuli needs to be remedied. There is a need for research that classifies same-aged/grade participants into different reading groups (average reading, reading impairment) using the same pre-experimental measures and then investigates the decoding and spelling abilities using the same stimuli for both tasks.

Purpose of this Study

This study was designed to investigate both decoding and spelling skills of fourth graders in order to determine if differences exist between the reading groups (average reading, reading impairment) as a factor of three broad stimulus categories: word type, orthographic type, and word length. Limitations in reading and spelling research often include the treatment of reading/decoding and spelling as two mutually exclusive tasks. The use of different stimuli to measure decoding accuracy and spelling accuracy does not allow for comparison of the client's performance. There is a need for the same stimuli to be used to determine if the client has differences between decoding ability and spelling ability. Researchers from different disciplines (e.g., psychology, linguistics, education, and speech-language pathology) use a variety of assessment tools to assess reading and spelling abilities, and may have different research focuses and philosophies that may affect the research results. The use of different assessment tools that include different stimuli have led to wide variation in results and limited generalizability of results across disciplines (e.g., psychology, speech-language pathology, reading). Second, the stimuli are not categorized by word type (real words/nonsense words), orthographic type (phonetic/nonphonetic), and word length (monosyllabic/multisyllabic), which affects the initial grouping of participants based on performance, and the interpretation of results. Third, participants have traditionally been grouped by reading-level, grade-level, or chronological age, resulting in differences in experience up to two years, using assessment tools that may not have controlled for stimuli differences, which adds additional potential for misclassification of disabilities (reading impairment or typical reading). Individual differences that may be artifacts of decoding experience, provision of therapy services, and familiarity with test stimuli, are rarely reported because mean group performance is typically reported. The classification of participants may be influenced by the philosophical beliefs and specific aims of the research, which may lead to biased results and affect generalizability and limit clinical application. Finally, experimental design differences, such as the use of single subtests to determine the presence of a primary reading impairment and/or spelling disorder to categorize participants, that do not contain the same stimuli, may affect the research results and conclusions reached based on those results, and limit clinical application. All of the differences in pre-experimental and experimental conditions (age, stimuli, and research bias) have led to problems with differential analysis and interpretation of the reported results, limiting generalizability. Comprehensive research of decoding accuracy and spelling accuracy should take into account and control for the previously mentioned variables (age-related experience of participants, differences in stimuli, and subtyping stimuli by orthographic type) in order to provide scientifically sound results. There is no research-supported diagnostic protocol available for the assessment of reading impairments and related spelling deficits using the same stimuli balanced for word type (real, nonsense), orthographic type (phonetic, nonphonetic), and word length.

Rationale for Study

There is a paucity of research that has investigated the decoding and spelling abilities for children in the fourth-grade (grade-matched) using the same stimuli categorized by word type (real, nonsense), orthographic type (phonetic, nonphonetic), and word length (1-5 syllables). A thorough review of the reading and spelling research literature has included variation in decoding and spelling abilities resulting from differences in the ages of participants, the assessment tools used, the stimuli used within the assessment tools, and the criteria for subtyping (definitions) reading impairments, which has led to difficulties in the interpretation of results. First, the differences between the groups of age-matched and/or reading-level matched participants may include more than a 24 month range. Second, the assessment tools that are used to assess reading and spelling performance use broad categories such as, real words (sight-words) and nonsense words (pseudowords), but do not always subtype the words by orthographic type (phonetic, nonphonetic), which limits differential diagnosis of the specific subtype of reading impairment (dysphonetic, dyseidetic, mixed). Third, the assessment tools used to group the participants is not always presented in the research study, so the interpretation of the data is difficult, and there is no chance for replication of the research. The specific criteria for classification of participants with and primary reading impairment and average reading abilities are not readily available. Less than 10% of speech-language pathologists (SLP) assess either or both reading/decoding abilities and spelling abilities as part of a standard speech and language assessment, for various reasons such as lack of time, experience, and limited resources. Finally, written spelling assessment is not consistently completed for children with language-based reading impairments for many of the same reasons. Therefore, a complete profile of the child's decoding and spelling abilities is rarely completed and the SLP may be using limited information as the basis of clinical decisions (e.g., diagnosis and intervention) for reading and spelling deficits. There is a need for the standardized assessment tools to classify the stimuli into useful information for differential diagnosis. Two children may receive the same standard score, but may have a different profile of errors, which is misleading. There is a need for more sensitive assessment tools that differentiate not only broad word types (real sight-words, nonsense words), but also categorize the stimuli into the different orthographic types (phonetic, nonphonetic), and word lengths, to allow for differential diagnosis and child-specific intervention. There is also a need for SLPs to do item-specific error analyses to determine if there are trends in both the correct answers and the incorrect answers, to support differential diagnosis of reading impairments.

The purpose of this study had three components. First, to investigate reading accuracy and spelling accuracy for a group of fourth-graders (grade-matched) with and without reading impairments using one set of stimuli categorized by word type (real, nonsense), orthographic type (phonetic, nonphonetic), and word length (1-5 syllables). Second, to provide research-based support about single word reading and spelling as they relate to the Shared-Components Dual-Route Model of Reading and Spelling (Rapcsak et al., 2007) and the Double Deficit Hypothesis of Reading Disorders (Wolfe & Bowers, 1999) using the same 100 word stimuli categorized by word type, orthographic type, and word length for the reading and spelling tasks. Third, to inform speech-language pathologists that current assessment tools are not sensitive enough to determine the specific areas of reading and spelling strengths and weaknesses because the stimuli are not classified beyond the broad categories of real and nonsense words. It is important to categorize the stimuli using both word type and orthographic type for the assessment and intervention for children with reading impairments.

The present study examined the single word decoding and spelling accuracy for fourth-graders (between ages of 9-11 years), because at this grade, children should be using both phonological and visual/lexical decoding to read fluently and be reading to learn, and functioning at Chall's Stage 3 Learning New Information from Reading in the areas of reading, math, science, history, and geography. Fourth graders at this age/stage should have more developed decoding and spelling abilities than younger children and less variability in both decoding and reading comprehension performance. Information gathered in this study will benefit both clinical and educational speech-language pathologists by providing research-based diagnostic criteria that can be used to diagnosis a primary reading impairment, subtype the reading impairment, and determine the related spelling skills based on both strengths and weaknesses. Spelling performance will also be provided and compared to reading/decoding skills which will aid in the composition of a profile for each child. The results of this research will provide support for the shared-component dual-route model of reading and spelling, the double deficit hypothesis of reading disorders, and relationship between reading and spelling processes by assessing oral language, reading, and written language. This will provide a functional and realistic framework for differential diagnosis and the development of treatment for children with and without primary reading impairments and spelling disorders.

Research Question

The research question for this study was whether an association exists between decoding accuracy and spelling accuracy for fourth-graders with and without reading impairments as a function of specific lexical parameters (word type, orthographic type, and word length) presented in a series of decoding and spelling tasks? The null hypothesis was there was not an association between the decoding accuracy and spelling accuracy for this study.

Decoding/Reading and spelling are often considered "two sides of the same coin" (Ehri, 1986) and require similar knowledge such as letter recognition, phoneme-grapheme knowledge, phonological awareness, orthographic knowledge, morphological knowledge, and semantic knowledge (Apel & Masterson, 2001; Apel, Masterson, & Niessen, 2004; Apel et al., 2011; Bear & Templeton, 1998; Caravolas, Hulme, & Snowling, 2001; Ehri & McCormick, 1998; Fischer, Shankweiler, & Liberman, 1985; Moats, 2000; Plaut, 2005; Schlagal, 2001; Siegler, 1996). Reading has one different variable, and naming speed (Bowers & Wolf, 1993; Denckla & Rudel, 1976; Nation & Snowling, 2004; Strattman & Hodson, 2005) that has been reported as a source of reading impairment. Reading stage theorists (Chall, 1997) and spelling stage theorists (Ehri, 1986, 1990) have provided a framework (Figure 3) that illustrates the out of phase development of reading skills and spelling skills, with reading developing before spelling (Snowling, 1985). Therefore, it is possible for a child to read at the logographic stage and spell at the alphabetic stage, which results in the child being able to write regular words but not read them (Bryant & Bradley, 1980) and vice versa (Goswami & Bryant, 1990). A majority of the research results that has focused on either the reading accuracy or spelling accuracy for children and adults has included average group differences and similarities, there is a need to investigate individual differences that are present for both the participants and in the stimuli used in the research.

Individual differences. Children need to have correctly-spelled phonological and visual representations of words (sight-words, Cassar & Treiman, 1997; Swank & Catts, 1994) stored in memory or they will have more difficulty recognizing and decoding words in print (Ehri, 1998) during reading activities and constructing (writing) words during spelling activities (Snow, Griffin, & Burns, 2005). In 1973, Boder reported children with reading impairments have misspellings that are similar to their decoding deficits. Children with dyseidetic decoding will use a phonetic spelling strategy to spell both phonetic and nonphonetic words and nonwords. Misspellings may include nonphonetic and unintelligible and may be semantic substitutions (e.g., "laugh" for funny, "quack" for duck). In contrast, children with dysphonetic decoding profile will write all words phonetically, even sight words. Misspelling patterns may include omitted letters, (e.g., "sed" for said, "lisn" for listen). Finally, children with dysphonetic-dyseidetic decoding patterns will have misspellings that may be completely undecipherable (e.g., "wen" for strong). The spelling level that can be determined using the *Boder Test of Reading and Spelling* (Boder & Jarrico, 1982) was based on research that stated normal readers can correctly spell 70% of known words at their grade level. The greatest level at which a reader spells at least 70%

correctly can be regarded as the child's spelling level (p. 72). The reader is to read as many levels as it takes to get 70% of known words spelled correctly for each grade level to establish a spelling level. A discrepancy of as little as one year could be a significant discrepancy since the stimulus words are in order by grade level. The stimuli that are used for assessment and treatment are very important, so it is necessary to address the differences that may occur in relation to the stimuli.

Stimulus related effects. Word type (real, nonsense), orthographic type (phonetic, nonphonetic), and word length (1-3 syllables, 1-13 letters) are three variables that have been investigated separately or in conjunction with one other variable (e.g., word type – word length) and had differential effects on decoding accuracy for English and other languages (e.g, French, Italian). Historically, one or two categories (word type, orthographic type, word length) have been used for word stimuli in research, Boder (1969, 1973; Boder & Jarrico, 1982) compared decoding and spelling accuracy for real words classified by orthographic type (phonetic, nonphonetic) for children and adults. Van den Broeck & Geudens (2012) and Wolfe & Bowers (1999) reported decoding differences for children using real and nonsense words (word type). A word length effect (number of letters) was reported by many researchers using real and nonsense words (Balota et al., 2007; Bonin et al., 2013; Duncan & Seymour, 2003; Leach et al., 2003; New et al., 2006; Spinelli et al., 2005) for both the accuracy and response latency for children with a primary reading impairment and with typically developing reading skills. Typically, children with reading impairments have lower decoding accuracy (more incorrect responses) for single word decoding tasks as a function of orthographic type (phonetic, nonphonetic) compared to children without reading impairments. Children with reading impairments also have longer response latency times (time between seeing the stimuli and responding) as a function of word length, characterized by increased response latency with an increase in word length. Specifically, New et al. (2006), reported a U-shaped curve for response times with longer response times for words between 3-5 letters and 8-13 letters as a function of the word length (number of letters) for both real words and nonwords compared to adults without reading impairments (Figure 5). Reading and spelling require similar knowledge such as, as the relationship between letter and sounds which are used to form mental representations (Ehri, 2000). Children with reading impairments are also at risk for spelling deficits (Boder, 1973; Cassar & Treiman, 1997; Ehri, 1998; Snowling, 1985).

Normally developing readers become proficient at both phonological decoding and visual-lexical decoding in the fourth grade (Chall, 1983, 1997). Children with reading impairments have decoding deficits that persist into adulthood (Bruck, 1992; Greenberg, Ehri, & Perin, 1997; Rack, Snowling, & Olson, 1992; van Ijzendoorn & Bus, 1994). The participants in this study were grade-matched (fourth graders) who should all be proficient with phonological and visual-lexical decoding both real and nonsense words. The real word stimuli used in this study were listed in the Dolch word lists for first to fifth grade (Dolch, 1936) and a compilation of words that should be familiar to children in the fourth grade (Perkins, 2013), and Fry (2000).

CHAPTER II: METHODS

Participants

Twenty-three fourth-grade children between the ages of 9-11;10 years (*M* = 10.3 years, *SD* = 3.2 years) participated in this study. They were recruited from Greenville, NC and surrounding areas via the East Carolina University Research listserv and Announce, and printed flyers. There were 13 girls and 10 boys with normal or corrected vision, hearing, and motor skills, and attention (that was controlled by medication based on information obtained from the parents); and no motor or cognitive deficits (e.g., Intellectual Deficits). The parent of each participant reviewed and completed a Parental Consent Form (Appendix A). One parent completed a Case History Form for each participant (Appendix B). The pre-experimental testing and experimental tasks were presented during one session of between 90 minutes and 120 minutes, with a 10 minute break between the sets of tasks. The pre-experimental and experimental tasks were completed in the East Carolina University Reading Lab in the Department of Communication Sciences and Disorders. This study was approved by the East Carolina University Institutional Review Board.

Pre-experimental Tests

The pre-experimental testing included a hearing screening, nonverbal intelligence measure, receptive vocabulary measure, single word decoding subtests, and a written spelling test. The order of the pre-experimental tests was consistent for all participants. First, all children passed a hearing screening at 20dBHL for 500 Hz, 1,000 Hz, and 2,000 Hz per ASHA guidelines (1997) administered by the PI. Second, the *Raven's Coloured Progressive Matrices* (*RCPM*;

Raven, 1976) was administered in order to obtain a nonverbal intelligence measure. The *RCPM* provided a percentile rank as a measure of ability that corresponds with the raw score (max of 36) and the participant's age. Participants were required to obtain a percentile rank >10 to be included in this study. Finally, receptive vocabulary was assessed with the *Peabody Picture Vocabulary Test*-Fourth Edition *(PPVT-4*; Dunn & Dunn, 2007) that has an average range of 85-115; participants were required to have > 70 on this task to be included in this study.

Reading group criteria

Children with reading impairments typically have reported poor performance in school characterized by below average grades in reading, language arts, and mathematics, which are language intensive subjects. Diagnostic criteria for reading impairments (dyslexia) are dependent on decoding rate and accuracy and reading comprehension abilities (Catts & Kamhi, 2008, 2012). In this study, the participants were grouped into one of two groups: Average Reading Group and Reading Impairment Group using the following research criteria: performance on the single real word/nonsense word decoding scores obtained on the *Woodcock Reading Mastery Test* – Third Edition (*WRMT-III*; Woodcock, 2011) Word Identification and Word Attack subtests. Children were placed in the Average Reading Group with a standard score of $\geq$ 88 for this study to reduce the chance of presence of a reading disorder on both the *WRMT-III* Word Identification and Word Attack Subtests. Children were placed in the Reading Impairment Group with a standard score of < 88 for one of three conditions: either the *WRMT-III* Word Identification (sight-word decoding deficit), or Word Attack (phonological decoding deficit) subtest, or both subtests (Word Identification and Word Attack).

Spelling performance for all children was obtained using the *Test of Written Spelling-5* (*TWS-5*; Larson, Hammill, & Moats, 2013). Children were considered Average Spellers with a standard score of ≥ 88, children with scores of < 88 were considered Below Average Spellers.

Experimental Measures

Experimental Task 1: Decoding single words

Each participant was asked to read single 50 real words and 50 nonsense words presented on a Dell Laptop computer screen for a set time of 2,000 ms with a 500 ms interstimulus cue (+) between stimuli using Super Lab 5 (Cedrus Corporation, 2014). The 50 experimental real word stimuli were modeled after the categories contained within the *Boder Test of Reading and Spelling* (Boder & Jarrico, 1982) and the Dolch sight word lists for second, third, fourth, and fifth grades (Dolch, 1936; Perkins, 2013). The 50 experimental nonsense word stimuli were modeled after the categories contained within the following assessment instruments, the *Children's Test of Nonword Repetition* (Gathercole, Willis, Baddeley, & Emslie, 1993) and the *Nonword Decoding Test* (International Dyslexia Association, 2003). The order of the real word and nonsense word decoding tasks was randomized.

A total of 100 stimulus words: 50 real words (Appendix C) and 50 nonsense words were used for the single word decoding task. Subcategories included five stimulus words for each word length of one to five syllables for the two orthographic types (phonetic, nonphonetic). The stimuli were presented randomly within two blocks (real words and nonsense words) between 1-5 syllables (word length) at a consistent rate of presentation of 2,000 ms with a 500 ms cue (+) on the laptop screen using Super Lab 5 (Cedrus Corporation, 2014). Printed instructions were presented on the computer screen along with verbal instructions in order to allow all children the chance of understanding the instructions. All children were asked to repeat the instructions, to make sure they all knew what was expected. There were 3 practice stimuli of both real words and nonsense words to familiarize the participants with the task. The participants were asked to orally decode the stimulus (word/nonsense word) they saw on the computer screen as quickly and accurately as possible. The naming accuracy (whether the stimuli were correctly named) was recorded by hand by the primary investigator in real time and digitally recorded on a handheld recorder placed on the table near the participant.

Experimental Task 2: Spelling Decision Task

The Spelling Decision Task included the same 50 real words used in experimental task 1: single word decoding task (Appendix D). The words were equally balanced in two orthographic categories (25 phonetic, 25 nonphonetic) of increasing word length (between 1-5 syllables) from the real word stimuli. Twenty-five of the 50 real words were presented as correctly spelled words and 25 incorrectly spelled words on the computer screen. The stimulus word was visible on the computer screen for a maximum of 2,000 ms (the timer reset for each subsequent stimulus set) with a 500 ms "+" with an accompanying tone was presented between each word using Super Lab 5 (Cedrus Corporation, 2014). Printed instructions were presented on the computer screen along with verbal instructions in order to allow all children the chance of understanding the instructions. All children were asked to repeat the instructions, to make sure they all knew what was expected. Each child was asked to say "yes" if the word on the computer screen was correctly spelled and to remain silent if the word on the screen in incorrectly spelled. There were

3 practice items to familiarize the participant with the task. Response accuracy hand recorded by the PI and digitally recorded using a hand held recorder. The words presented orally were taken from the initial list of stimuli used in the experimental task 1 (See Appendix C). The presentation of each word type (real words and nonsense words) was counterbalanced.

Experimental Task 3: Written Spelling

Each child was asked to write a real word or nonsense word that had been prerecorded by the primary investigator that was presented by the computer using the Audacity program , using a pencil without an eraser and a piece of lined paper. The same stimuli 100 words, 50 real (Appendix C) and 50 nonsense words from the experimental task 1: single word decoding task were used for this written spelling task to control for variation that is present in all previous research. For example, the real word stimuli were said in isolation (e.g., “car”), followed by the word in a sentence (e.g., “the car is red.”), and finally, the word was repeated in isolation (e.g., “car”). Nonsense words were presented one time without a sentence, followed by a 5 second delay, finally, the nonsense word was repeated in isolation. Each child was asked to write all of the nonsense words that were prerecorded and presented by the computer. The presentation of word types (real vs. nonsense) was counterbalanced.

Statistical Analysis

In this study, the null hypothesis of no relationship between the independent variables characterized by interactions was investigated. If there was an interaction, the null hypothesis was rejected and the interactions were analyzed using post hoc Fisher’s least significant difference (LSD) comparisons because of the small sample size. All hypotheses were tests at

$p < .05$. Pre-experimental test scores were compared using independent t-tests to determine if there was a difference between the two reading groups on the pre-experimental tests. Experimental accuracy (proportional means) were analyzed using repeated measures analyses of variance (ANOVAs) for each of the three experimental tasks (single word decoding, spelling decision, and written spelling). Assumptions (normality, homogeneity of variance) were checked for each repeated measures ANOVA model, if the sphericity assumption was not met for Mauchly's Test of Sphericity, the Greenhouse-Geiser correction was used. The proportional accuracy means were calculated and compared for the independent variables reading group (average reading group), word type (real, nonsense), orthographic type (phonetic, nonphonetic), and word length (1-5 syllables) for each of the experimental tasks. The dependent variable for all three experimental tasks was accuracy (proportion means). All hypotheses were tests at $p < .05$. Post hoc Fisher's least significant difference (LSD) comparisons were used to investigate significant interactions. There was no adjustment for Type I error because of the small sample size for this study. In order to determine if there were relationships between the pre-experimental and experimental tasks, Pearson correlations were calculated for ease of interpretability and due to the presence of raw accuracy scores. Additional Pearson correlations were calculated to determine the significance of relationships between the decoding accuracy and spelling accuracy experimental tasks for each of the reading groups.

CHAPTER III: RESULTS

Historically, research that is focused on reading accuracy and or spelling accuracy has included groups of participants that are categorized in reading-matched or spelling-matched groups, resulting in a large range of ages and grade levels. This study investigated the reading and spelling accuracy for fourth-graders, because at this grade, children should be using both phonological and visual/lexical decoding to read fluently and reading to learn, (Chall's Stage 3) in science, history, and geography. Fourth graders should have more decoding automaticity and spelling abilities than children in first to third grade. This study included children in one grade level (fourth-grade) to control for reading experience and chronological age. The participants for this study included 23 fourth-grade children, between the ages of 8;11 years and 11;10 years. Two reading groups, an average reading group and a reading impairment group were formed using the results of the *Woodcock Reading Mastery Test-III* (Woodcock, 2011). There were 17 children with average reading abilities (mean age 10.10 years) in the control group and 6 children (mean age = 10.50 years) with a reading impairment served as the experimental group.

Pre-experimental Tests

Means, standard deviations, and ranges are presented for both reading groups in Table 2. All children passed a hearing screening at 20dB HL for 1000, 2000, and 4000 Hz (ASHA, 2011) to ensure they would be able to complete all tasks. The *Raven's Progressive Coloured Matrices* (Raven, 1976) was administered to obtain a general nonverbal intelligence measure. Results included a range of percentile ranked scores from 10 to 95 (M = 76.09, SD = 29.43). An independent t-test compared the mean percentile ranked scores for the reading groups to determine if there was a significant difference, the results included, t (21) = 2.93, p = .008, d =

.290, which was significant. The Average Reading Group (M = 85, SD = 15) performed significantly better than the Reading Impairment Group (M = 50, SD = 44) on the *Raven's Progressive Coloured Matrices.*

The *Peabody Picture Vocabulary Test-4* (Dunn & Dunn, 1997) was administered to control for receptive vocabulary abilities. An independent t-test compared the mean performance for the Average Reading Group and the Reading Impairment Group resulted in, t (21) = .94, p = .356, d = .041, which was not significant. No significant difference was found between the groups for the *PPVT-4* which controlled for the receptive vocabulary abilities. The *PPVT-4* was not used as a covariate because this test was used as participant criteria which limited the range of standard scores. The *PPVT-4* standard scores were strongly correlated with the pre-experimental tests and experimental tasks and may be used as a covariate in future analysis.

The standard scores on the *Woodcock Reading Mastery Test-III* (Woodcock, 2011) Word Identification and Word Attack subtests were used to assign the children into either the Average Reading Group (AR) or the Reading Impairment Group (RI). Children who obtained standard scores of < 88 on one or both of the subtests for this study were placed in the Reading Impairment (experimental) group. The average range for the standard scores on the *WRMT-III* is 85-115; however, the cutoff of 88 was used in this study to ensure the reading abilities of the groups were different. Independent sample t-tests were calculated to determine the relationship between the RI and AR group performance on the two *WRMT-III* subtests. An independent-samples t-test was used to compare the mean scores on the word identification subtest, results included a significant difference between the means of the two groups, t (21) = 3.59, p = .002, *d* = .381. The word identification mean of the average reading group was significantly higher (*M* = 114, *SD* = 17) than the word identification mean of the reading impairment group (*M* = 84, *SD* = 14). An independent-samples *t-test* was used to compare the mean scores on the word attack subtest, results included a significant difference between the means of the two groups, t (21) = 4.72, $p < .001$, $d = .515$. The word attack mean of the average reading group was significantly higher (*M* = 111, *SD* = 14) than the word identification mean of the reading impairment group (*M* = 80, *SD* = 12). Overall, the average reading group scored higher on both word decoding subtests, the word identification and word attack subtests compared to the reading impairment group.

Finally, an independent-samples *t-test* was conducted to compare the mean scores on the *Test of Written Spelling-5*. No significant difference was found, t (21) = 2.06, $p = .052$, $d = .168$. The mean for the average reading group (*M* = 104, *SD* = 15) was not significantly different from the reading impairment group (*M* = 91, *SD* = 8). In this study, five children (three children with reading impairment and two children with average reading) received standard scores below 89 on the *TWS-5* and were classified as below average spellers, the remaining 18 children had average spelling abilities.

Table 2

Pre-Experimental Means, Standard Deviations (SD) and Ranges for by Group for Age, Nonverbal Intelligence (RPCM), Receptive Verbal Vocabulary (PPVT-4), Reading Ability (WRMT-III Word Identification and Word Attack subtests), and Written Spelling (TWS-5)

Variable	**Mean**	**SD**	**Range**
Reading Impairment Group			
Age	10.50	.70	9.60 - 11.70
Raven's Progressive Coloured Matrices	50	44	10 – 95
PPVT-4	106	18	79 – 123
WRMT-III			
Word Identification	84	14	64 – 106
Word Attack	80	12	68 – 101
TWS-5	91	8	83 – 103
Average Reading Group			
Age	10.10	.80	9.10 – 11.10
Raven's Progressive Coloured Matrices	85	15	50 – 95
PPVT-4	114	17	88 – 145
WRMT-III			
Word Identification	114	17	88 – 145
Word Attack	111	14	90 – 143
TWS-5	104	15	85 – 141

Note. Age is reported in years. The *RPCM* are reported as percentiles (Mean = 50). *PPVT-4*, *WRMT-III*, and *TWS-5* are reported as standard score quotients (Mean = 100, ± 15).

Experimental Tasks

Experimental Task 1: Decoding single words

In the first experimental task, each participant was asked to read single 50 real words and 50 nonsense words presented on a Dell Laptop computer screen for a set time of 2,000 ms with a 500 ms interstimulus cue (+) between stimuli using Super Lab 5 (Cedrus Corporation, 2014). Decoding accuracy (proportional mean), the average of correct responses for the five words of each word length, was the dependent variable. The independent variables were reading group (reading impairment, average), word type (real, nonsense), orthographic type (phonetic, nonphonetic), and word length (1-5 syllables).

Decoding Accuracy proportional means, standard deviations, and ranges were calculated and are presented by reading group for the real words (Table 3) and for the nonsense words (Table 4). A 2 (reading group) x 2 (word type) x 2 (orthographic type) x 5 (word length) repeated measures ANOVA was conducted to determine if there was a significant difference for decoding accuracy between the reading groups. The decoding accuracy Repeated Measures ANOVA Interactions and Main Effects for Reading Groups as a Function of Word Type, Orthographic Type, and Word Length are presented in Table 5. Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(9) = 17.58$, $p = .041$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.73$). The results of the decoding accuracy repeated measures ANOVA included a four-way interaction of Reading Group x Word Type x Orthographic Type x Word Length, $F(4, 18) = 1.40$, $p = .274$, partial $\eta^2 = .237$, that was not significant. There was a significant three-way interaction for Word Type x Orthographic Type x Word Length, $F(4, 18) = 7.34$, $p = .001$, partial $\eta^2 = .620$, that is presented in Figure 6. Despite the significant three-way interaction and its impact, decoding accuracy consistently declined with word length, real words always had higher accuracy than nonsense words, with a differing trend for real and nonsense words, but phonetic vs. nonphonetic showed no clear trend. The presence of the three-way significant interaction led to the rejection of the null hypothesis. Post hoc LSD comparison results included significant differences in the decoding accuracy (proportional means) between the word types as a function of orthographic type and word length (Figure 7). Real word decoding accuracy (proportional means) (M = .86) was compared to the nonsense word decoding accuracy (proportional means) (M = .46), there was a significant difference between the word types, $F(4, 19) = 8.06$, $p = .001$, $\eta^2 = .207$, characterized by higher decoding accuracy for the real words compared to the nonsense words. Additional investigation was completed using post hoc LSD comparisons for each word type to determine where the significant interactions were and to determine if significant differences existed between orthographic types (phonetic, nonphonetic) for each word length. Real word decoding accuracy comparisons as a function of orthographic type and word length results included significant differences in mean decoding accuracy between the real phonetic and nonphonetic words for the 1 syllable words, $F(1, 44) = .59$, $p = .448$, $\eta^2 = .672$; for the 2 syllable words, $F(1, 44) = 9.57$, $p = .003$, $\eta^2 = .318$; and for the 3 syllable words, $F(1, 44) = 12.43$, $p = .001$, $\eta^2 = .251$. However, differences in mean decoding accuracy between orthographic types were not significant for the 4 syllable words, $F(1, 44) = .44$, $p = .513$, $\eta^2 = .696$, or 5 syllable words, $F(1, 44) = .19$, $p = .667$, $\eta^2 = .412$. Nonsense word decoding accuracy comparisons as a function of orthographic type and word length results included significant difference between the phonetic and nonphonetic word for only the 2 syllable words, $F(1, 44) = 6.02$, $p = .018$, $\eta^2 = .166$, was significant. There were no significant differences between the phonetic nonsense words and nonphonetic nonsense words for the 1 syllable words, $F(1, 44) = 3.27$, $p = .077$, $\eta^2 =$

.293; the 3 syllable words, $F(1, 44) = .14$, $p = .713$, $\eta^2 = .104$; the 4 syllable words, $F(1, 44) = .34$, $p = .564$, $\eta^2 = .125$, or the 5 syllable words, $F(1, 44) = .18$, $p = .673$, $\eta^2 = .147$. The decoding accuracy differences between the word types as a function of word length was expected. Real words are typically decoded more accurately compared to nonsense words, resulting from familiarity with the decoding of the real words which were taken from widely used third to fifth grade spelling word lists.

There was a significant main effect for reading group, $F(1, 21) = 5.49$, $p = .029$, partial $\eta^2 = .207$, that indicated there was a significant difference in decoding accuracy between the reading groups, Average Reading Group ($M = .71$, $SD = .184$) decoding accuracy was higher than the Reading Impairment Group ($M = .51$, $SD = .183$) decoding accuracy which was expected. The presence of a difference in decoding accuracy for the experimental stimuli supports the grouping of the children using the results of pre-experimental decoding test performance.

Table 3

Experimental Task 1: Proportional Means, Standard Deviations, and Ranges for Decoding Accuracy Raw Scores for Real Words by Reading Group as a Function of Orthographic Type and Word Length

Variable	Mean	*SD*	Range
Reading Impairment Group	**.75**	**.09**	**0 – 1.00**
Phonetic	**.79**	**.11**	**.72 - 1.00**
1 syllable	.90	.11	0 - 1.00
2 syllable	.90	.17	0 - 1.00
3 syllable	1.00	.00	1.00
4 syllable	.63	.21	0 - 1.00
5 syllable	.53	.27	0 - 1.00
Nonphonetic	**.71**	**.13**	**.56 - .92**
1 syllable	.97	.82	0 - 1.00
2 syllable	.83	.82	0 - 1.00
3 syllable	.67	.21	0 - 1.00
4 syllable	.53	.24	0 - 1.00
5 syllable	.57	.20	0 - 1.00
Average Reading Group	**.89**	**.11**	**0 – 1.00**
Phonetic	**.93**	**.11**	**.44 – 1.00**
1 syllable	1.00	.00	1.00
2 syllable	1.00	.00	1.00
3 syllable	.98	.06	0 - 1.00
4 syllable	.82	.21	0 - 1.00
5 syllable	.84	.27	0 - 1.00
Nonphonetic	**.86**	**.14**	**.52 – 1.00**
1 syllable	.95	.09	0 - 1.00
2 syllable	.89	.12	0 - 1.00
3 syllable	.86	.22	0 - 1.00
4 syllable	.80	.23	0 - 1.00
5 syllable	.78	.24	0 - 1.00

Table 4

Experimental Task 1: Proportional Means, Standard Deviations, and Ranges for Decoding Accuracy Raw Scores for Nonsense Words by Reading Group as a Function of Orthographic Type and Word Length

Variable	Mean	*SD*	Range
Reading Impairment Group	**.27**	**.30**	**0 – 1.00**
Phonetic	**.32**	**.26**	**.08 -- .80**
1 syllable	.67	.19	0.00 – 1.00
2 syllable	.47	.33	0.00 – 1.00
3 syllable	.17	.41	0.00 – 1.00
4 syllable	.17	.32	0.00 – 1.00
5 syllable	.13	.33	0.00 – 1.00
Nonphonetic	**.22**	**.35**	**.00 - .92**
1 syllable	.40	.38	0.00 – 1.00
2 syllable	.20	.31	0.00 – 1.00
3 syllable	.17	.41	0.00 – 1.00
4 syllable	.17	.41	0.00 – 1.00
5 syllable	.17	.41	0.00 – 1.00
Average Reading Group	**.53**	**.28**	**0 – 1.00**
Phonetic	**.56**	**.27**	**.16 – 1.00**
1 syllable	.87	.25	0.00 – 1.00
2 syllable	.78	.27	0.00 – 1.00
3 syllable	.49	.36	0.00 – 1.00
4 syllable	.34	.34	0.00 – 1.00
5 syllable	.34	.40	0.00 – 1.00
Nonphonetic	**.50**	**.30**	**.12 – 1.00**
1 syllable	.75	.30	0.00 – 1.00
2 syllable	.53	.37	0.00 – 1.00
3 syllable	.54	.37	0.00 – 1.00
4 syllable	.43	.38	0.00 – 1.00
5 syllable	.26	.37	0.00 – 1.00

Table 5

Experimental Task 1: Decoding Accuracy Repeated Measures ANOVA Interactions and Main Effects

Effect	**F**	**df**	***p***
Four-way interaction			
Reading Group x Word Type x Orthographic Type x Word Length	1.40	(4,18)	.274
Three-way interactions			
Reading Group x Word Type x Orthographic Type	.03	(1,21)	.492
Reading group x Word Type x Word Length	2.76	(4,18)	.060
Reading group x Orthographic Type x Word Length	1.04	(4,18)	.413
Word type x Orthographic Type x Word Length	7.34	(4,18)	.001
Two-way interactions			
Reading Group x Word Type	1.20	(1,21)	.285
Reading Group x Orthographic Type	.17	(1,21)	.687
Reading Group x Word Length	.21	(4,18)	.928
Word Type x Orthographic Type	.03	(1,21)	.861
Word Type x Word Length	3.89	(4,18)	.019
Orthographic Type x Word Length	3.16	(4,18)	.039
Main effects			
Reading Group	5.49	(1,21)	.029
Word Type	59.90	(1,21)	<.001
Orthographic Type	10.59	(1,21)	.004
Word Length	19.12	(4,18)	<.001

p=.05

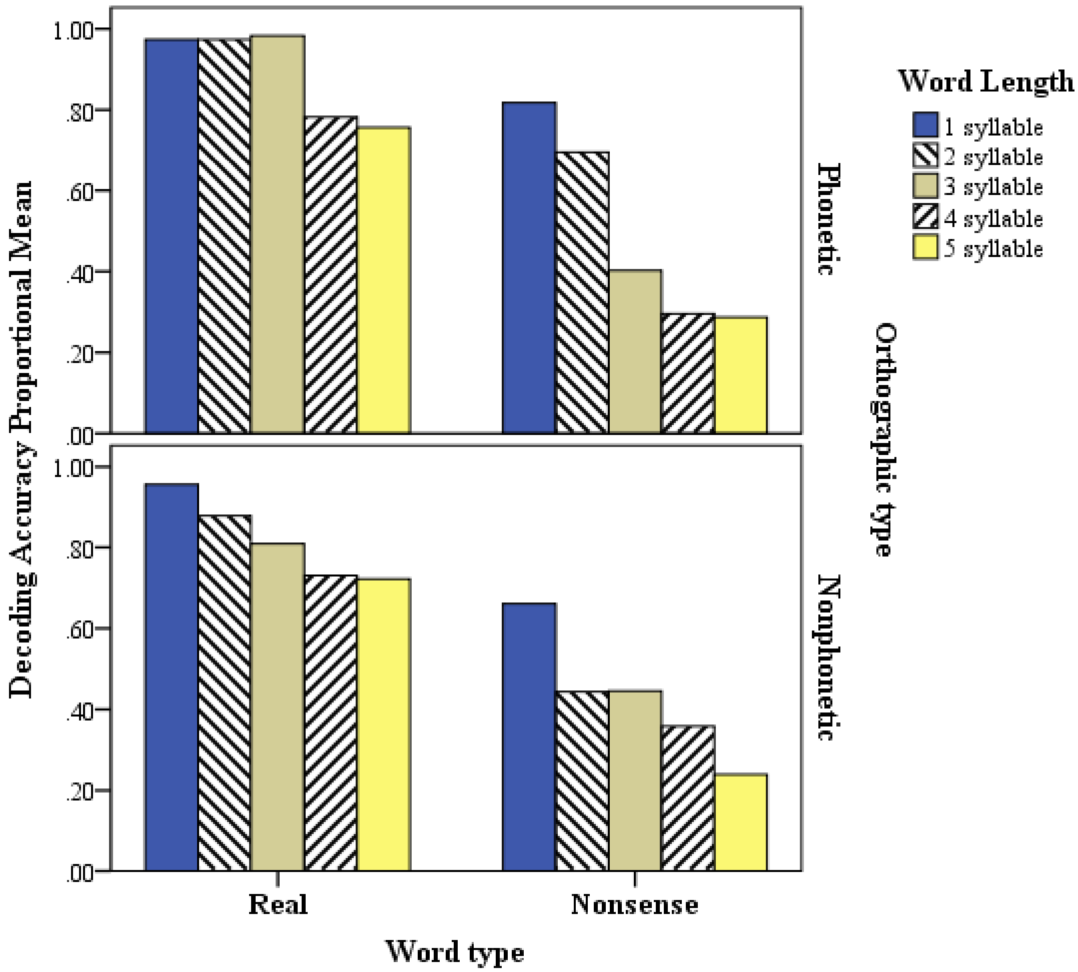

Figure 6: Experimental Task 1: Decoding Accuracy (proportional means) Interaction as a Function of Word Type, Orthographic Type, and Word Length

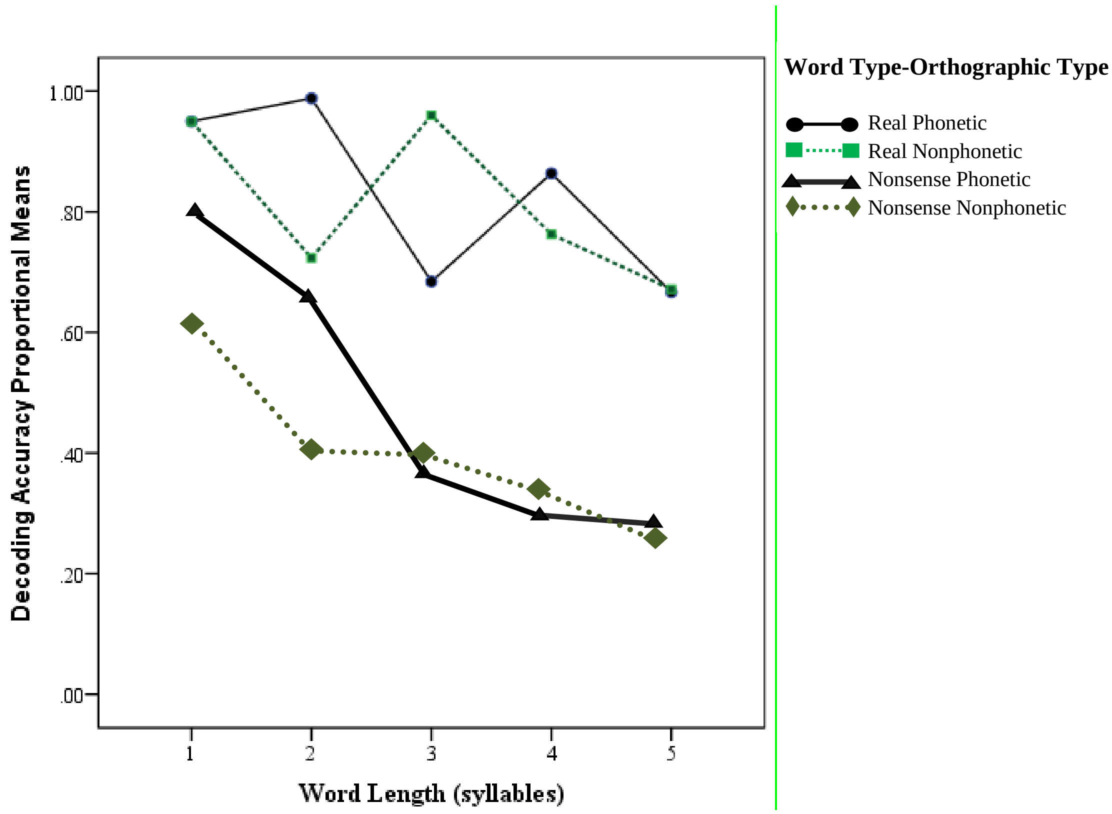

Figure 7: Experimental Task 1: Decoding Accuracy (proportional means) Interaction for Both Word Types as Function of Orthographic Type and Word Length

Experimental Task 2: Spelling Decision Task

The Spelling Decision Task included the same 50 real words used in experimental task 1: single word decoding task (Appendix D). All participants were required to provide a verbal response of "yes" if the word presented on the computer screen was correctly spelled and silence (nonresponse) if the presented word was incorrectly spelled. An investigation of the possible mean accuracy (number of correctly identified, correctly spelled words) differences between the reading groups (average reading group, reading impairment group) for detecting correctly spelled real words when given a binary choice (correct-incorrect) was conducted. There were three independent variables for this task: reading group (average reading, reading impairment), orthographic type (phonetic, nonphonetic), and word length (1-5 syllables). The dependent variable was proportional mean accuracy for this experimental spelling decision task.

Spelling Decision Accuracy proportional means, standard deviations, and ranges are presented in Table 6. A 2 (reading group) x 2 (orthographic type) x 5 (word length) repeated measures ANOVA was used to investigate the relationships between the reading groups, orthographic types, and word lengths for the spelling decision task. The spelling decision accuracy Repeated Measures ANOVA Interactions and Main Effects for Reading Groups as a Function of Word Type, Orthographic Type, and Word Length are presented in Table 7. Mauchly's test indicated that the assumption of sphericity had not been violated, $\chi^2(9) = 8.56$, $p = .481$, so no adjustment was needed. The three-way interaction of Reading Group x Orthographic Type x Word Length $F(4, 17) = 1.81$, $p = .173$, $\eta^2 = .299$ was not significant. The two-way interaction of Orthographic Type x Word Length $F(4, 17) = 5.32$, $p = .006$, $\eta^2 = .556$ was significant and is presented in Figure 8. The presence of the three-way significant interaction led to the rejection of the null hypothesis. Post hoc LSD comparisons were calculated to determine nature of the spelling decision accuracy differences between the two orthographic types. The spelling decision post hoc comparison results included significant spelling decision accuracy differences between the phonetic and nonphonetic words for the 2 syllable words of $F(1,42) = 10.66$, $p = .002$, $\eta^2 = .202$ (phonetic, $M = .91$ and nonphonetic, $M = .61$) and 3 syllable words of $F(1,42) = 9.72$, $p = .008$, $\eta^2 = .163$ (phonetic, $M = .97$ and nonphonetic, $M = .77$). However, the spelling decision accuracy differences between the phonetic and nonphonetic words were not significant for the 1 syllable words, $F(1,42) = .41$, $p = .526$, $\eta^2 = .010$, for the 4 syllable words of $F(1,42) = .90$, $p = .348$, $\eta^2 = .021$, or the 5 syllable words of $F(1,42) = 2.49$, $p = .122$, $\eta^2 = .056$.

Table 6

Experimental Task 2: Spelling Decision Accuracy Proportional Means, Standard Deviations, and Ranges for Real Words as a Function of Reading Group, Orthographic Type and Word Length

Variable	**Mean**	***SD***	**Range**
Reading Impairment Group			
Real Words			
Phonetic	**.85**	**.18**	**0.00 – 1.00**
1 syllable	.92	.20	.50 – 1.00
2 syllable	1.00	.00	1.00
3 syllable	1.00	.00	1.00
4 syllable	.75	.27	.50 – 1.00
5 syllable	.58	.49	0.00 – 1.00
Nonphonetic	**.74**	**.15**	**0.00 – 1.00**
1 syllable	.83	.28	.33 – 1.00
2 syllable	.42	.36	0.00 – 1.00
3 syllable	.89	.17	.67 – 1.00
4 syllable	.71	.25	.50 – 1.00
5 syllable	.83	.41	0.00 – 1.00
Average Reading Group			
Real Words			
Phonetic	**.85**	**.15**	**0.00 – 1.00**
1 syllable	.94	.17	.50 – 1.00
2 syllable	.88	.29	0.00 – 1.00
3 syllable	.96	.11	.67 – 1.00
4 syllable	.69	.36	0.00 – 1.00
5 syllable	.81	.31	0.00 – 1.00
Nonphonetic	**.82**	**.18**	**0.00 – 1.00**
1 syllable	.92	.19	.33 – 1.00
2 syllable	.69	.36	0.00 – 1.00
3 syllable	.73	.30	0.00 – 1.00
4 syllable	.81	.19	.50 – 1.00
5 syllable	.94	.25	0.00 – 1.00

Table 7

Experimental Task 2: Spelling Decision Accuracy Repeated Measures ANOVA Interactions and Main Effects for Means by Reading Group, as a Function of Orthographic Type, and Word Length

Effect	**F**	**df**	***p***
Three-way interactions			
Reading Group x Orthographic Type x Word Length	1.81	(4,17)	.173
Two-way interactions			
Reading Group x Orthographic Type	2.09	(1,20)	.164
Reading Group x Word Length	1.63	(4,17)	.212
Orthographic Type x Word Length	5.32	(4,17)	.006
Main effects			
Reading Group	.33	(1,20)	.570
Orthographic Type	8.20	(1,20)	.010
Word Length	3.38	(4,17)	.036

$p = .05$

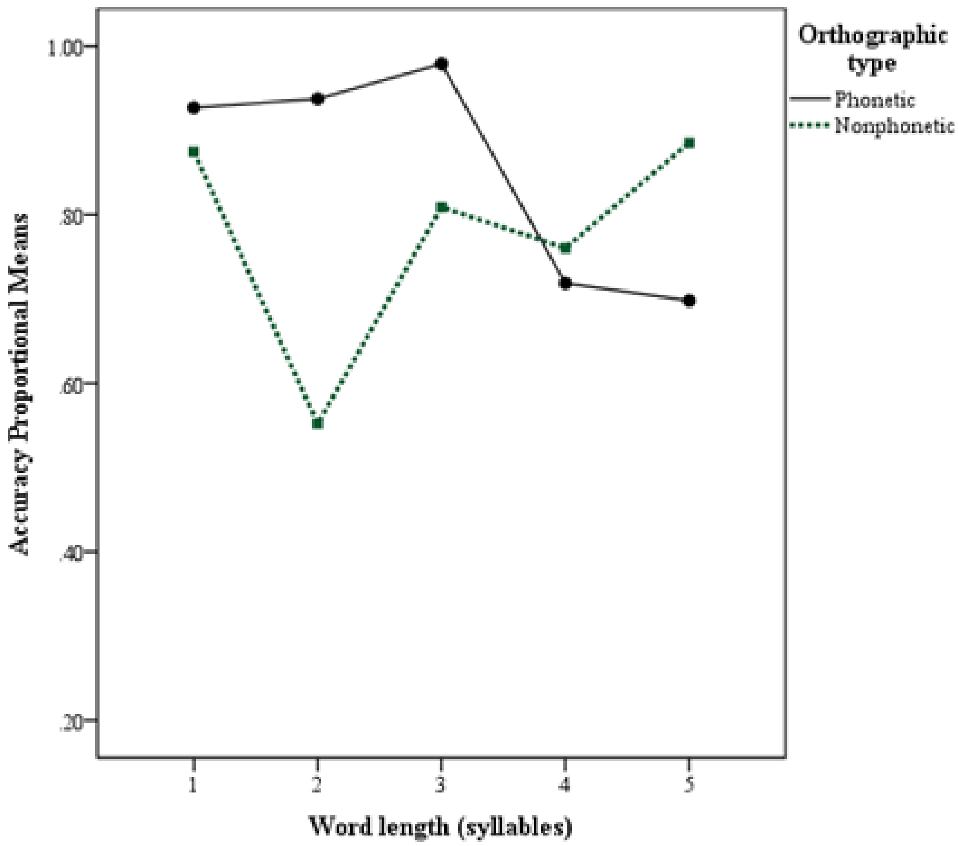

Figure 8: Spelling Decision Accuracy (proportional means) as a Function of Orthographic Type and Word Length

Experimental Task 3: Written Spelling

The Written Spelling Task required each participant to write a real word or nonsense word that had been prerecorded by the primary investigator that was presented auditorilly by the computer using the Audacity program, using a pencil without an eraser and a piece of lined paper. The same 100 stimulus words, 50 real words (Appendix C) and 50 nonsense words from the single word decoding task (experimental task 1) were used for this written spelling task to control for variation. The real word stimuli were presented in isolation (e.g., “car”), followed by the word in a sentence (e.g., “the car is red.”), and finally, the word was repeated in isolation (e.g., “car”). Nonsense words were presented two times with a five second pause without a sentence. The child was asked to write nonsense words that were orally presented by the examiner. The order of the presentation of word types (real vs. nonsense) was counterbalanced.

Written Spelling Accuracy proportional means, standard deviations, and ranges were calculated for the reading groups as a function of word type and orthographic type, the real word results are presented in Table 8 and the nonsense word results are presented in Table 9. Mauchly’s test indicated that the assumption of sphericity had been violated, $\chi^2(9) = 43.43$, $p < .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.83$). A 2 (reading group) x 2 (word type) x 2 (orthographic type) x 5 (word length) repeated measures ANOVA was conducted to investigate the relationship between the written spelling accuracy proportional means as a function of reading group (reading impairment, average reading), word type (real, nonsense), orthographic type (phonetic, nonphonetic), and word length (1-5 syllables). The written spelling accuracy repeated measures ANOVA interactions and main effects results are presented in Table 10. The four-way interaction of Reading Group x Word Type x Orthographic Type x Word Length, F (4,110) = .75, p = .561, partial η^2 = .047, was not significant. There were two significant three-way interactions which led to the rejection of the null hypothesis.

The first significant three-way interaction for written spelling accuracy proportional means was for Reading Group x Word Type x Word Length, $F(4,110) = 4.18$, $p = .003$, partial η^2 = .167, (see Figure 9). Post hoc LSD comparisons for the reading groups as a function of word type and word length were conducted to determine the nature of the written spelling accuracy differences. The reading group differences for the written spelling accuracy proportional means were not significant for the 1 syllable real words, $F(1,113) = .74$, $p = .392$, partial η^2 = .006, and for 2 syllable real words, $F(1,113) = 2.25$, $p = .139$, partial η^2 = .023. In contrast, there were significant written spelling accuracy differences between the reading groups for 3 syllable real words $F(1,113) = 10.86$, $p = .001$, partial η^2 = .088 (Average Reading group M = .56, Reading Impairment group M = .38); for 4 syllable real words, $F(1,113) = 15.60$, $p < .001$, partial η^2 = .121 (Average Reading group M = .35, Reading Impairment group M = .15); and for 5 syllable real words, $F(1,113) = 12.64$, $p = .001$, partial η^2 = .101, (Average Reading group M = .37, Reading Impairment group M = .12). The Written Spelling Accuracy post hoc LSD comparisons for reading groups as a function of word type and word length for the nonsense words included significant written spelling accuracy between reading group differences for 1 syllable words, $F(1,113) = 10.71$, $p = .001$, partial η^2 = .087, (Average Reading group M = .22, Reading Impairment group M = .07); for 2 syllable words, $F(1,120) = 4.90$, $p = .029$, partial η^2 = .039, (Average Reading group M = .65, Reading Impairment group M = .33); and for 3 syllable words, $F(1,120) = 7.99$, $p = .005$, partial η^2 = .062 (Average reading group M = .50, Reading Impairment group $M = .16$). There were not significant between group differences for the 4 syllable words, $F(1,120) = .36$, $p = .547$, partial $\eta^2 = .003$, and 5 syllable words, $F(1,120) = 266$, $p = .106$, partial $\eta^2 = .022$. The written spelling accuracy decreased for both reading groups as a function of word type and word length.

The second significant three-way interaction was for Word Type x Orthographic Type x Word Length, $F(4,110) = 4.80$, $p = .001$, partial $\eta^2 = .152$, (Figure 13). Post hoc LSD comparisons were calculated to evaluate the spelling accuracy proportional means for the word types and word lengths. Written spelling accuracy differences between the real phonetic words compared to the nonsense phonetic words were significant for 1 syllable words, $F(1,113) = 10.71$, $p = .001$, partial $\eta^2 = .087$ (real phonetic, $M = .06$, nonsense phonetic, $M = .29$); for 2 syllable words, $F(1,120) = 4.90$, $p = .029$, partial $\eta^2 = .039$, (real phonetic, $M = .85$, nonsense phonetic, $M = .33$); for 4 syllable words, $F(1,120) = 7.99$, $p = .005$, partial $\eta^2 = .062$, (real phonetic, $M = .31$, nonsense phonetic, $M = .69$), and for 5 syllable words $F(1,113) = 7.99$, $p = .005$, partial $\eta^2 = .062$, (real phonetic, $M = .74$, nonsense phonetic, $M = .17$). The written spelling accuracy differences between the real phonetic words and nonsense phonetic words included between group differences for the 4 syllable words, $F(1,120) = .36$, $p = .547$, partial $\eta^2 = .003$, and 5 syllable words, $F(1,120) = 2.66$, $p = .106$, partial $\eta^2 = .022$ that were not significant. Nonsense word written spelling accuracy (proportional means) results are presented as a function of orthographic type and word length in Figure 10. Post hoc LSD results included between orthographic type (phonetic, nonphonetic) differences for 1 syllable words, $F(1, 228) = 229.43$, $p < .001$, partial $\eta^2 = .502$, (real nonphonetic, $M = .31$, nonsense nonphonetic, $M = .07$); for 2 syllable words, $F(1, 113) = 7.34$, $p < .001$, partial $\eta^2 = .779$, (real nonphonetic, $M = .27$, nonsense nonphonetic, *M* = .03); for 3 syllable words $F(1, 113) = 45.72$, $p < .001$, partial $\eta^2 =$ .167, (real nonphonetic, *M* = .80, nonsense nonphonetic, *M* = .55); for 4 syllable words, $F(1, 228) = .182$, $p < .001$, partial $\eta^2 = .620$, (real nonphonetic, *M* = .54, nonsense nonphonetic, *M* = .16); and for 5 syllable words, $F(1, 113) = 5.87$, $p = .016$, partial $\eta^2 = .025$, (real nonphonetic, *M* = .29, nonsense nonphonetic, *M* = .11). Written spelling accuracy decreased for both of the reading groups, word types, and orthographic types, with an increase in word length. The real phonetic and nonsense phonetic written spelling accuracy scores were parallel to each other and the real nonphonetic and the nonsense nonphonetic written spelling accuracy scores were parallel to each other. In contrast, interactions were found between the real phonetic and real nonphonetic written spelling accuracy score pattern and between the nonsense phonetic and nonsense nonphonetic written spelling accuracy score pattern (Figure 10).

Differences in the written spelling accuracy between the reading groups as a function of the word type and word length, and the word type, orthographic type, and word length support the need for more specific analysis of written spelling accuracy using word type and orthographic type as factors for diagnostic and intervention purposes.

Table 8

Experimental Task 3: Written Spelling Accuracy Proportional Means, Standard Deviations, and Ranges for Real Words by Groups as a Function of Orthographic Type, and Word Length

Variable	Mean	*SD*	Range
Reading Impairment Group			
Real Words	**.34**	**.16**	**.10 – .60**
Phonetic	**.39**	**.25**	**0 – 1.00**
1 syllable	.86	.35	0 – 1.00
2 syllable	.77	.39	0 – 1.00
3 syllable	.53	.51	0 – 1.00
4 syllable	.07	.25	0 – 1.00
5 syllable	.10	.31	0 – 1.00
Nonphonetic	**.29**	**.15**	**0 – 1.00**
1 syllable	.71	.45	0 – 1.00
2 syllable	.34	.49	0 – 1.00
3 syllable	.17	.38	0 – 1.00
4 syllable	.10	.31	0 – 1.00
5 syllable	.00	.00	0.00
Average Reading Group			
Real Words	**.54**	**.23**	**0 – .90**
Phonetic	**.59**	**.22**	**0 – 1.00**
1 syllable	.99	.11	0 – 1.00
2 syllable	.86	.35	0 – 1.00
3 syllable	.81	.39	0 – 1.00
4 syllable	.40	.50	0 – 1.00
5 syllable	.34	.48	0 – 1.00
Nonphonetic	**.50**	**.30**	**0 – 1.00**
1 syllable	.82	.38	0 – 1.00
2 syllable	.60	.49	0 – 1.00
3 syllable	.34	.48	0 – 1.00
4 syllable	.36	.48	0 – 1.00
5 syllable	.00	.00	0.00

Table 9

Experimental Task 3: Written Spelling Accuracy Proportional Means, Standard Deviations, and Ranges for Nonsense Words by Reading Group as a Function of Orthographic Type, and Word Length

Variable	Mean	*SD*	Range
Reading Impairment Group			
Nonsense Words	**.14**	**.14**	**0 - .40**
Phonetic	**.20**	**.21**	**0 – 1.00**
1 syllable	.54	.51	0 – 1.00
2 syllable	.20	.41	0 – 1.00
3 syllable	.07	.25	0 – 1.00
4 syllable	.03	.18	0 – 1.00
5 syllable	.00	.00	0.00
Nonphonetic	**.09**	**.13**	**0 – 1.00**
1 syllable	.33	.48	0 – 1.00
2 syllable	.07	.25	0 – 1.00
3 syllable	.00	.00	0.00
4 syllable	.03	.18	0 – 1.00
5 syllable	.00	.00	0.00
Average Reading Group			
Nonsense Words	**.32**	**.19**	**0 – .80**
Phonetic	**.41**	**.28**	**0 – 1.00**
1 syllable	.75	.43	0 – 1.00
2 syllable	.35	.48	0 – 1.00
3 syllable	.21	.41	0 – 1.00
4 syllable	.08	.28	0 – 1.00
5 syllable	.05	.21	0 – 1.00
Nonphonetic	**.22**	**.18**	**0 – 1.00**
1 syllable	.64	.48	0 – 1.00
2 syllable	.20	.40	0 – 1.00
3 syllable	.16	.37	0 – 1.00
4 syllable	.12	.32	0 – 1.00
5 syllable	.04	.19	0 – 1.00

Table 10

Experimental Task 3: Written Spelling Accuracy Proportional Means Interactions and Main Effects as a Function of Reading Group, Word Type, Orthographic Type, and Word Length

Effect	**F**	**df**	***p***
Four-way interactions			
Reading group x word type x orthographic type x word length	.75	(4, 110)	.561
Three-way interactions			
Reading group x word type x orthographic type	.01	(1, 113)	.919
Reading group x word type x word length	4.18	(4, 110)	.003
Reading group x orthographic type x word length	.523	(4, 110)	.719
Word type x orthographic type x word length	4.80	(4, 110)	.001
Two-way interactions			
Reading group x word type	3.02	(1, 113)	.085
Reading group x orthographic type	.57	(1, 113)	.452
Reading group x word length	.26	(4, 110)	.901
Word type x orthographic type	11.40	(1, 113)	.001
Word type x word length	5.89	(4, 110)	< .001
Orthographic type x word length	9.54	(4, 110)	< .001
Main effects			
Reading Group	26.69	(1, 113)	< .001
Word type	239.40	(1, 113)	< .001
Orthographic type	60.88	(1, 113)	< .001
Word length	112.00	(4, 110)	< .001

p = .05

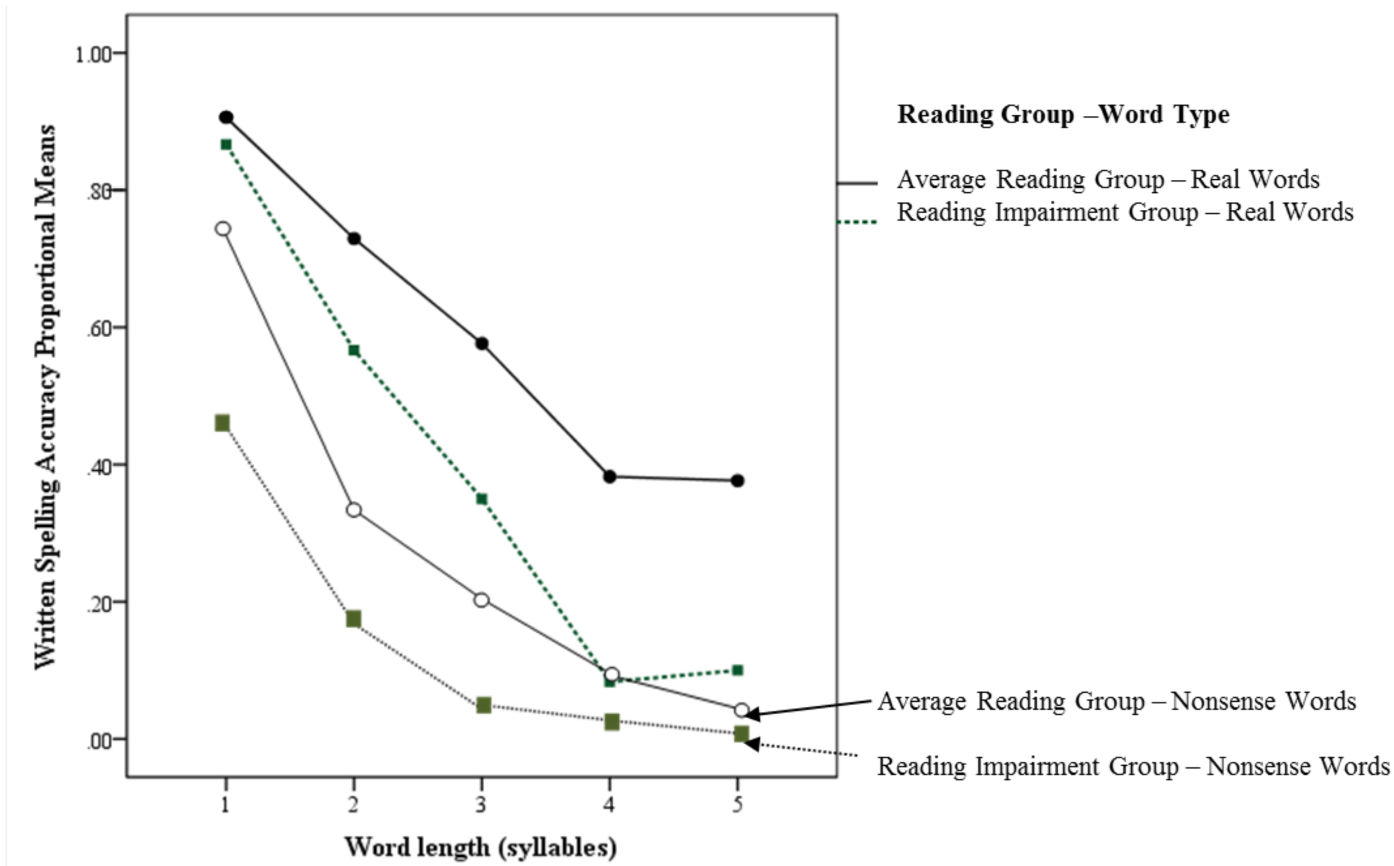

Figure 9: Experimental Task 3: Written Spelling Accuracy (proportional mean) Interaction for the Reading Groups as a Function of Word Type and Word Length

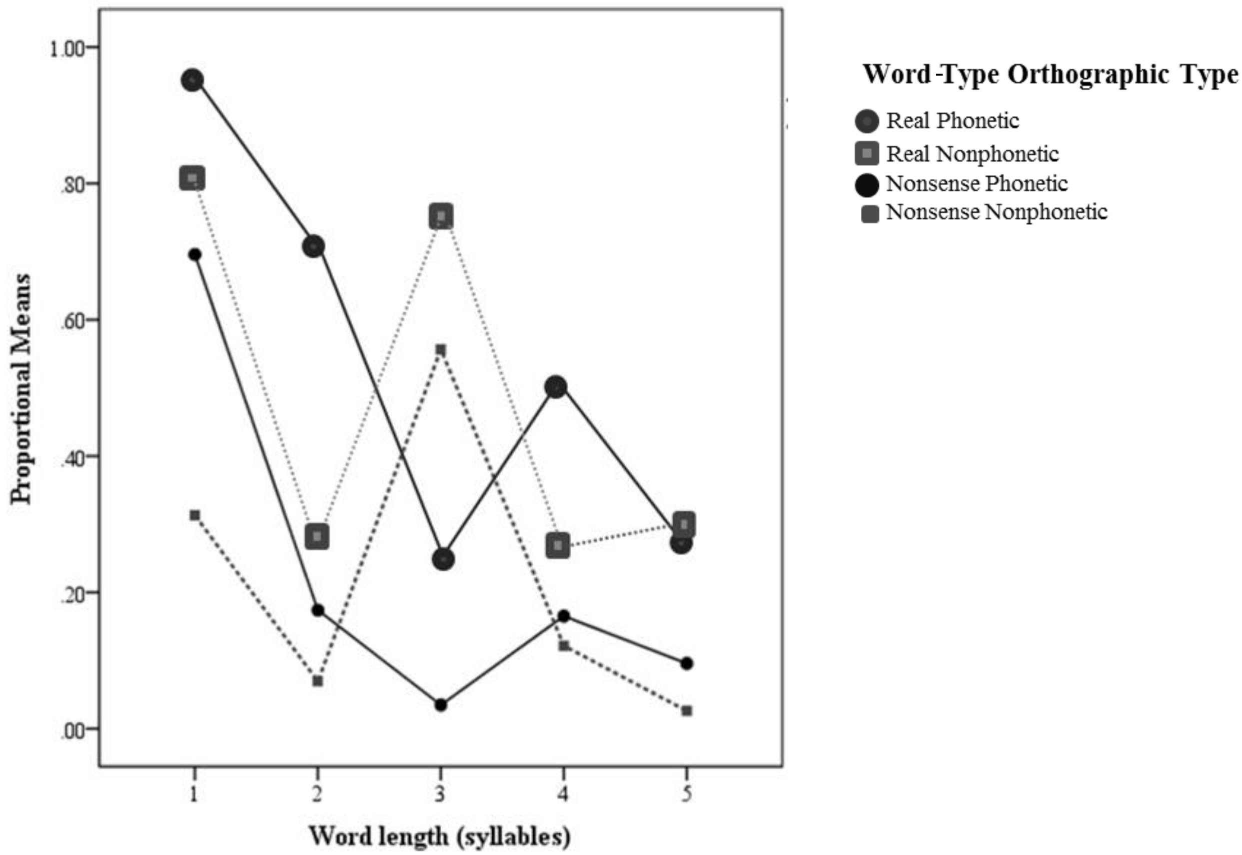

Figure 10: Experimental Task 3: Written Spelling Accuracy (proportional means) Interaction for Word Type as a Function of Orthographic type and Word Length

Decoding Accuracy and Spelling Accuracy Association

Was there a relationship between the decoding accuracy and spelling accuracy for fourth-graders with and without reading impairments for 100 single word stimuli categorized by word type (real words, nonsense words), orthographic type (phonetic, nonphonetic), and word length (1-5 syllables) presented in a series of decoding and spelling tasks? Pearson correlation coefficients were calculated to investigate the relationships between the decoding accuracy (Experimental Task 1) and written spelling accuracy (Experimental Task 3) as a function of word types (real, nonsense) and orthographic types (phonetic, nonphonetic) (Table 11). There was a significant moderate correlation for decoding accuracy for real phonetic words and written spelling accuracy for real phonetic words, $r(115) = .518$, $p < .001$. There was a significant moderate positive correlation for decoding accuracy for real nonphonetic words and written spelling accuracy for real nonphonetic words, $r(115) = .348$, $p < .001$. There was a significant moderate positive relationship for the decoding nonsense phonetic words and written spelling nonsense phonetic words, $r(115) = .523$, $p < .001$. Finally, there was a significant, but weaker positive relationship for the decoding accuracy for nonsense nonphonetic words and written spelling accuracy for nonsense nonphonetic words, $r(115) = .271$, $p = .003$.

Reading Group Correlations

Pearson correlation coefficients were also calculated to investigate the relationships between the decoding accuracy (Experimental Task 1) and written spelling accuracy (Experimental Task 3) for each reading group across word types and orthographic types (Table 12).

Average Reading Group Correlations

The decoding accuracy and spelling accuracy for the Average Reading Group correlations were also calculated to investigate the relationships between the decoding accuracy (experimental task 1) and written spelling accuracy (experimental task 3) for both word types and orthographic types. A significant moderate correlation was found for the decoding accuracy of real phonetic words and spelling accuracy of real phonetic words, $r(111) = .430$, $p < .001$. A significant weak positive correlation was found for the decoding accuracy of real nonphonetic words and written spelling accuracy of real nonphonetic words, $r(111) = .262$, $p = .005$. There was a significant moderate positive correlation found for decoding accuracy of nonsense phonetic words and written spelling accuracy of nonsense phonetic words, $r(111) = .447$, $p < .001$. In contrast, there was a weak positive relationship for the decoding accuracy of nonsense nonphonetic words and written spelling accuracy of nonsense nonphonetic words, $r(111) = .160$, $p = .090$, that was not significant. The significant correlations between decoding accuracy and written spelling accuracy were stronger for the real phonetic words ($r = .430$) and the nonsense phonetic words ($r = .447$) compared to the real nonphonetic words ($r = .262$) and the nonsense nonphonetic words ($r = .160$), which indicated a difference as a function of orthographic type for the average reading group in this study.

Reading Impairment Group Correlations

The decoding accuracy and spelling accuracy relationship for the Reading Impairment Group was investigated using Pearson correlations across word types and orthographic types. A positive weak correlation was found for the decoding accuracy of real phonetic words and written spelling accuracy real phonetic words, $r(30) = .222$, $p = .120$, was not significant. The weak negative correlation was found for the decoding accuracy of real nonphonetic words and written spelling accuracy of real nonphonetic words, *r*(30) = -.063, *p* =.371, was not significant. A significant positive moderate correlation was found for the decoding accuracy of nonsense phonetic words and written spelling accuracy of nonsense phonetic words, *r*(30) = .323, *p* = .041. There was a weak positive correlation for the decoding accuracy of nonsense nonphonetic words and written spelling accuracy of nonsense nonphonetic words, *r*(30) = .184, *p* = .165, that was not significant. The decoding accuracy and written spelling accuracy correlation results were mixed for the reading impairment group was only significant for the nonsense phonetic words (*r* = .323), but not for the real phonetic words (*r* = .222), the real nonphonetic words (*r* = -.063), or the nonsense nonphonetic words (*r* = .184), and did not follow a consistent trend as a function of orthographic type.

Pre-Experimental Test and Experimental Tasks Correlations

Correlational analyses were conducted to investigate the relationships between the reading and spelling abilities (pre-experimental test scores) and the experimental accuracy scores for this study (Table 13). Pearson correlations were used for this study because there was a small sample size (*N* = 23). There was a significant moderate positive correlation for the *Raven's Progressive Coloured Matrices Test* and the *Peabody Picture Vocabulary Test-4 (PPVT-4)*, *r*(23) = .54, *p* =.008. A significant moderate positive correlation was found for the for the *Raven's Progressive Coloured Matrices Test*, and the *Woodcock Reading Mastery Test-III* (*WRMT-III*) Word Identification subtest, *r*(23) = .63, *p* =.001. There was a significant moderate positive correlation for the *Raven's Progressive Coloured Matrices Test* and the Decoding Accuracy for Real words, *r*(23) = .44, *p* =.036. There was a significant moderate positive correlation for the

Raven's Progressive Coloured Matrices Test and the Spelling Decision Accuracy, *r*(23) = .49, *p* =.020. There was a significant moderate positive correlations for the *Raven's Progressive Coloured Matrices Test* and Spelling Accuracy for Nonsense words, *r*(23) = .44, *p* =.001. A weak positive correlation between the *Raven's Progressive Coloured Matrices Test* and the *WRMT-III* Word Attack subtest, *r*(23) = .39, *p* =.066, was not significant. A weak positive correlation between the *Raven's Progressive Coloured Matrices Test* and *TWS-5*, *r*(23) = .24, *p* =.274, was not significant. The weak positive correlation between the *Raven's Progressive Coloured Matrices Test* and Decoding Accuracy for Nonsense Words, *r*(23) = .24, *p* =.274, was not significant.

PPVT-4: A significant moderate positive correlation was found for the *PPVT-4* and the *WRMT-III* Word Identification subtest score, *r*(23) = .55, *p* =.006. A significant moderate positive correlation was found for the *PPVT-4* and the *Test of Written Spelling-5*, *r*(23) = .44, *p* =.034. A significant moderate positive correlation was found for the *PPVT-4* and the Spelling Decision Accuracy, *r*(23) = .52, *p* =.012. A significant moderate positive correlation was found for *PPVT-4* and the Spelling Accuracy for Real words, *r*(23) = .52, *p* =.012. A significant moderate positive correlation was found for the *PPVT-4* and the Spelling Accuracy for Nonsense words, *r*(23) = .59, *p* =.003. A weak positive correlation between the *PPVT-4* and the *WRMT-III* Word Attack subtest, *r*(23) = .29, *p* =.066, was not significant. A weak positive correlation between the *PPVT-4* and Decoding Accuracy for Real words, *r*(23) = .31, *p* =.145, was not significant. A weak positive correlation between the *PPVT-4* and Decoding Accuracy for Nonsense words, *r*(23) = .03, *p* =.879, was not significant.

WRMT-III Word Identification: A significant moderate positive correlations was found for the *WRMT-III* Word Identification subtest and the *Raven's Progressive Coloured Matrices*

Test, *r*(23) = .63, *p* =.001. A significant moderate positive correlations was found for the *WRMT-III* Word Identification subtest and the *PPVT-4*, *r*(23) = .63, *p* =.001. A significant strong positive correlations was found for the *WRMT-III* Word Identification subtest and the *WRMT-III* Word Attack subtest, *r*(23) = .88, *p* < .001. A significant strong positive correlation was found for the *WRMT-III* Word Attack subtest and the *TWS-5*, *r*(23) = .78, *p* < .001. A significant moderate positive correlation was found for the *WRMT-III* Word Identification subtest and the Decoding Accuracy for Real words, *r*(23) = .69, *p* < .001. A significant moderate positive correlation was found for the *WRMT-III* Word Identification subtest and the Decoding Accuracy for Nonsense words, *r*(23) = .64, *p* =.037. A significant moderate positive correlation was found for the *WRMT-III* Word Identification subtest and the Spelling Decision Accuracy, *r*(23) = .63, *p* =.002. A significant strong positive correlation was found for the *WRMT-III* Word Identification subtest and the Spelling Accuracy for Real Words, *r*(23) = .72, *p* < .001. A significant moderate positive correlation was found for the *WRMT-III* Word Identification subtest and the Spelling Accuracy for Nonsense words, *r*(23) = .60, *p* =.002.

WRMT-III Word Attack: A weak positive correlation was found for the *WRMT-III* Word Attack subtest and the *Raven's Progressive Coloured Matrices Test*, *r*(23) = .39, *p* =.066, was not significant. A weak positive correlations found for the *WRMT-III* Word Attack subtest and the *PPVT-4*, *r*(23) = .29, *p* =.175, was not significant. A significant strong positive correlation was found for the *WRMT-III* Word Attack subtest and *WRMT-III* Word Identification subtest score, *r*(23) = .88, *p* < .001. A significant strong positive correlation was found for the *WRMT-III* Word Attack subtest and the *TWS-5*, *r*(23) = .74, *p* < .001. A significant moderate positive correlation was found for the *WRMT-III* Word Attack subtest and the Decoding Accuracy for Real words, *r*(23) = .68, *p* < .001. A significant moderate positive correlation was found for the

WRMT-III Word Attack subtest and the Decoding Accuracy for Nonsense words, $r(23) = .55$, $p = .007$. A significant moderate positive correlation was found for the *WRMT-III* Word Attack subtest and the Spelling Decision Accuracy, $r(23) = .47$, $p = .027$. A significant moderate positive correlation was found for the *WRMT-III* Word Attack subtest and the Spelling Accuracy for Real Words, $r(23) = .69$, $p < .001$. A significant moderate positive correlation was found for the *WRMT-III* Word Attack subtest and the Spelling Accuracy for Nonsense words, $r(23) = .44$, $p = .036$.

TWS-5: A significant moderate positive correlation was found for the *TWS-5* and the *Raven's Progressive Coloured Matrices Test,* $r(23) = .24$, $p = .274$. A significant moderate positive correlation was found for the *TWS-5* and the *PPVT-4*, $r(23) = .44$, $p < .034$. A significant strong positive correlation was found for the *TWS-5* and the *WRMT-III* Word Identification subtest, $r(23) = .78$, $p < .001$. A significant strong positive correlation was found for the *TWS-5* and the *WRMT-III* Word Attack subtest, $r(23) = .74$, $p < .001$. A significant strong positive correlation was found for the *TWS-5* and the Decoding Accuracy for Real words, $r(23) = .67$, $p < .001$. A significant moderate positive correlation was found for the *TWS-5* and the Decoding Accuracy for Nonsense words, $r(23) = .58$, $p = .004$. A significant moderate positive correlation was found for the *TWS-5* and the Spelling Decision Accuracy, $r(23) = .46$, $p = .017$. A significant strong positive correlation was found for the *TWS-5* and the Spelling Accuracy for Real Words, $r(23) = .81$, $p < .001$. A significant moderate positive correlation was found for the *TWS-5* and the Spelling Accuracy for Nonsense words, $r(23) = .43$, $p = .041$. The moderate and strong positive correlations between the *TWS-5* and the spelling accuracy for the experimental tasks indicated that spelling abilities for the participants in this study were positively related for both real and nonsense words.

Table 11

Pearson Correlation Coefficients for Decoding Accuracy and Written Spelling Accuracy as a Function of Word Type and Orthographic Type

		Decoding Real Phonetic	**Decoding Real Nonphonetic**	**Decoding Nonsense Phonetic**	**Decoding Nonsense Nonphonetic**
Decoding Real Phonetic	Pearson Correlation	**1**	**.540****	**.382****	**.229***
	Sig. (2-tail)		.000	.000	.014
Decoding Real Nonphonetic	Pearson Correlation	**.540****	**1**	**.537****	**.485****
	Sig. (2-tail)	.000		.000	.000
Decoding Nonsense Phonetic	Pearson Correlation	**.382****	**.537****	**1**	**.704****
	Sig. (2-tail)	.000	.000		.000
Decoding Nonsense Nonphonetic	Pearson Correlation	**.229***	**.485****	**.704****	**1**
	Sig. (2-tail)	.014	.000	.000	
Spelling Real Phonetic	Pearson Correlation	**.518****	**.526****	**.428****	**.300****
	Sig. (2-tail)	.000	.000	.000	.014
Spelling Real Nonphonetic	Pearson Correlation	**.373****	**.348****	**.396****	**.226***
	Sig. (2-tail)	.000	.000	.000	.000
Spelling Nonsense Phonetic	Pearson Correlation	**.398****	**.520****	**.523****	**.364****
	Sig. (2-tail)	.000	.000	.000	.000
Spelling Nonsense Nonphonetic	Pearson Correlation	**.246***	**.351****	**.364****	**.271****
	Sig. (2-tail)	.014	.000	.000	.003

(N = 115) ** p = .01 and * p = .05

Table 12

Pearson Correlation Coefficients for Decoding Accuracy and Written Spelling Accuracy by Reading Group

		Overall (N = 23)	**Average Reading Group (N = 17)**	**Reading Impairment Group (N = 6)**
Decoding Real Phonetic & Spelling Real Phonetic	Pearson Correlation	**.518****	**.430****	**.222**
	Sig. (2-tail)	.000	.000	.120
Decoding Real Nonphonetic & Spelling Real Nonphonetic	Pearson Correlation	**.348****	**.262****	**- .063**
	Sig. (2-tail)	.000	.005	.371
Decoding Nonsense Phonetic & Spelling Nonsense Phonetic	Pearson Correlation	**.523****	**.537****	**.323***
	Sig. (2-tail)	.000	.001	.041
Decoding Nonsense Nonphonetic & Spelling Nonsense Nonphonetic	Pearson Correlation	**.271****	**.485**	**.184**
	Sig. (2-tail)	.003	.090	.165

** p =.01 and * p = .05

Table 13

Correlations for Pre-Experimental Test Performance Measures and Related Experimental Tasks

		Raven's	**PPVT-4**	**WRMT-III Word Identification**	**WRMT-III Word Attack**	**Test of Written Spelling-5**
Raven's Progressive Coloured Matrices	Pearson Correlation	1	**.536****	**.629****	.390	.238
	Sig. (2-tailed)		.008	.001	.066	.274
Peabody Picture Vocabulary Test-4	Pearson Correlation	**.536****	1	**.554****	.293	**.444***
	Sig. (2-tailed)	.008		.006	.175	.034
WRMT-III Word Identification	Pearson Correlation	**.629****	**.554****	1	**.878****	**.780****
	Sig. (2-tailed)	.001	.006		.000	.000
WRMT-III Word Attack	Pearson Correlation	.390	.293	**.878****	1	**.741****
	Sig. (2-tailed)	.066	.175	.000		.000
Test of Written Spelling-5	Pearson Correlation	.238	**.444***	**.780****	**.741****	1
	Sig. (2-tailed)	.274	.034	.000	.000	
Real Word Decoding Accuracy	Pearson Correlation	**.438***	.314	**.694****	**.678****	**.670****
	Sig. (2-tailed)	.036	.145	.000	.000	.000
Nonsense Word Decoding Accuracy	Pearson Correlation	.238	.034	**.437***	**.545****	**.575****
	Sig. (2-tailed)	.274	.879	.037	.007	.004
Spelling Decision Accuracy	Pearson Correlation	**.490***	**.520***	**.630****	**.470***	**.460***
	Sig. (2-tailed)	.020	.012	.002	.027	.017
Real Word Spelling Accuracy	Pearson Correlation	.352	**.517***	**.724****	**.693****	**.811****
	Sig. (2-tailed)	.099	.012	.000	.000	.000
Nonsense Word Spelling Accuracy	Pearson Correlation	**.440***	**.586****	**.604****	**.438***	**.429***
	Sig. (2-tailed)	.036	.003	.002	.036	.041

(N = 23) (** p = .01, *p = .05) Raven's = Raven's Progressive Coloured Matrices

CHAPTER IV: DISCUSSION

The aim of this study was three-fold. First, to investigate the comparison of reading accuracy and spelling accuracy for a group of fourth-graders (grade-matched) with and without reading impairments using one set of stimuli categorized by word type (real, nonsense), orthographic type (phonetic, nonphonetic), and word length (1-5 syllables). Second, to provide research-based support about single word reading and spelling as it relates to the Shared-Components Dual-Route Model of Reading and Spelling (Rapcsak et al., 2007) and the Double Deficit Hypothesis of Reading Disorders (Wolfe & Bowers, 1999) using the same 100 word stimuli for reading and spelling tasks categorized by word type, orthographic type, and word length. Third, to inform speech-language pathologists and other practitioners that current assessment tools are not sensitive enough to determine the specific areas of reading and spelling strengths and weaknesses because the stimuli are not classified beyond the broad categories of real and nonsense words. It is important to categorize the stimuli using both word type and orthographic type for the assessment and intervention for children with reading impairments.

Participants

Twenty-three fourth-grade children with normal hearing and vision were divided into two groups (reading impairment, average reading) based on their performance on the *WRMT-III* Word Identification and Word Attack subtests. The average reading group had 17 children, and the reading impairment group has six children. All 23 children completed three experimental tasks: 1) single word decoding, 2) spelling decision, and 3) written spelling.

Experimental Stimuli

The primary investigator chose the 100 word stimuli used in this study from multiple sources (standardized and unstandardized), because there are currently no assessment instruments that have word/lexical stimuli that are categorized by word type and orthographic type, have stimuli longer than 3 syllables for this grade level (fourth), and may be used to assess both reading and spelling performance. The real words and nonsense words used in this study were adapted from sources that have been used in reading and spelling research studies (e.g., Boder Test of Reading and Spelling and the Dolch sight-word list). The 50 experimental real word stimuli were modeled after the categories contained within the following assessment instruments *Boder Test of Reading and Spelling* (Boder & Jarrico, 1982) and the Dolch sight-word lists for second, third, fourth, and fifth grades (Dolch, 1936; Perkins, 2013). The 50 experimental nonsense word stimuli were modeled after the categories contained within the following assessment instruments the *Children's Test of Nonword Repetition* (Gathercole et al., 1993) which required children to repeat the orally presented nonwords, because it has words that are multisyllabic, between two and five syllables in length, and the *Nonword Decoding Test* (International Dyslexia Association, 2003) which provided decoding accuracy measures for difference age levels. In the present study, the classification of the stimuli, specifically the nonsense words into the orthographic types (phonetic, nonphonetic), was done by the primary investigator, with the intention of having balanced orthographic types and word lengths for the real and nonsense words. Additionally, the nonsense words were modeled after pseudoword stimuli and were not manipulated real words, were comparable in both word length and orthographic complexity to the real words that were selected.

Experimental Tasks

There were three experimental tasks used in this study. The first experimental task was a single word decoding task, that included all 100 stimulus words balanced for word type (50 real, 50 nonsense), orthographic type (25 phonetic, 25 nonphonetic), and word length (5 words for each word length 1-5 syllables), presented one at a time on the computer screen and all children were instructed to read the word as quickly and accurately as possible within a 2,000 ms time limit. The dependent variable was decoding accuracy and the independent variables included reading group (average reading, reading impairment), word type (real, nonsense), orthographic type (phonetic, nonphonetic), and word length (1-5 syllables). The second experimental task was a spelling decision task that included only the 50 real words. Each child was instructed to say "yes" if the word presented on the computer screen was spelled correctly and to remain silent if the word was incorrect. The dependent variable was spelling decision accuracy and the independent variables were reading group, orthographic type (phonetic, nonphonetic), and word length (1-5 syllables). The third experimental task was a written spelling task that included all 100 stimulus words. All words were presented via recording and each child was instructed to write the word they heard on a piece of lined paper. The dependent variable for the written spelling task was accuracy and the independent variables were reading group, word type, orthographic type, and word length.

Experimental Task 1: Single word decoding

A single word decoding task was used to answer the experimental question: Was there a difference between the mean accuracy (number correct) for decoding real words and nonsense words as a function of the number of syllables (1-5), or orthographic type (phonetic, nonphonetic) for fourth graders with and without reading impairments? In this task, each word was presented on the computer screen and all children were instructed to read the word as quickly and accurately as possible within a 2,000 ms time limit. The dependent variable was decoding accuracy. Independent variables included reading group (average reading, reading impairment), word type (real, nonsense), orthographic type (phonetic, nonphonetic), and word length (1-5 syllables). A total of 100 words, 50 real and 50 nonsense words, were used for this single word task.

Decoding accuracy results included a significant main effect of reading group ($p = .029$) characterized by higher decoding accuracy by the average reading group for both real and nonsense words compared to the reading impairment group, which was expected. There was a significant three-way interaction for word type, orthographic type, and word length ($p = .001$) (Figure 7). The decrease in decoding accuracy in relation to word type and word length in this study is similar to the decrease in decoding accuracy for both real and nonsense word types for both children (DeLuca et al., 2008; DiFilippo et al., 2006; Duncan & Seymour, 2003; Leach et al., 2003) and adults (Balota et al., 2007; Nazir et al., 2004; New, Ferrand, Pallier, & Brysbaert, 2006). Specifically, Duncan and Seymour (2003) reported a decrease in decoding accuracy for 11-year old children when there was an increase in the length of English words from bisyllabic (2 syllable) to trisyllabic (3 syllable) for both real and nonsense words. A major difference between the present study and the research by DeLuca et al. (2008) and colleagues was the lack of separation of the words by orthographic type, which limits the generalizability of DeLuca's (2008) results. The significant interaction (word type, orthographic type, word length) for the single word decoding accuracy supports the need for real words and nonsense words to be separated by orthographic type in order to conduct detailed error analyses and compile a decoding profile.

Experimental Task 2: Spelling Decision Task

Experimental Task 2: spelling decision task required all participants to determine if real words (50) presented on the computer screen were spelled correctly or not, there were 25 incorrectly spelled words and 25 correctly spelled words. Each participant was instructed to give a verbal response of "yes" was required if the word was correct and silence (nonresponse) was required if the word was incorrect. Printed instructions were presented on the computer screen along with verbal instructions in order to allow all children the chance of understanding the instructions. All children were asked to repeat the instructions, to make sure they all knew what was expected. There were 3 practice items to familiarize the participant with the task. The experimental question for the spelling decision task was: Is there a difference in the mean accuracy for detecting correctly spelled (real) words given a binary choice (correct-incorrect) for fourth-graders with and without a reading impairment?

Spelling decision accuracy was investigated using a 2 (reading group) x 2 (orthographic type) x 5 (word length) repeated-measures ANOVA. There was not a main effect of reading group which indicated both reading groups had similar spelling decision accuracy. There was a significant interaction for orthographic type x word length that indicated a difference between the phonetic accuracy and nonphonetic accuracy. The results of the spelling decision task included no difference between the reading groups, which was not expected. There was variation between the spelling decision accuracy for the phonetic and nonphonetic words as a function of word lengths. In this study, the participants selected more correctly spelled phonetic words that were short (1 syllable = 93%, 2 syllable = 91%, and 3 syllable = 97%) compared to selection of correctly spelled nonphonetic words of the same lengths (1 syllable = 89%, 2 syllable = 61%, and 3 syllable = 77%). In contrast, the opposite trend was true characterized by more nonphonetic words with 4 syllables = 78% and 5 syllables = 91% detected correctly more than the phonetic words of the same lengths 4 syllable = 70% and 5 syllables = 75% respectively. There was a significant difference (30%) between the phonetic and nonphonetic 2 syllable words, which was not expected. The spelling decision accuracy for this group of participants was better for short phonetic words (1 to 3 syllables) compared to nonphonetic words of the same length. However, the nonphonetic decision accuracy for the longer words (4 to 5 syllables) was better than the phonetic words of the same length. It is possible that the difference between the word lengths was due to the difference in the word structure. Additional error analysis may provide more insight into the differences between the orthographic types and word lengths.

To date, there are no research studies known to the PI that have assessed this specific type of spelling decision task using single real words categorized by orthographic type with word lengths of 1-5 syllables. Therefore, a comparison may be made with research reports using a similar task, lexical decision, which required participants to determine if a word form presented is a real word or not (English real words and nonsense words; Balota et al., 2007; French, New et al, 2003; and Italian real and nonsense words, DiFillipo et al., 2008). DiFillipo et al. (2008) reported a word length effect for both real and nonsense words, characterized by a linear decrease in accuracy with an increase in word length (number of letters). Both the spelling decision task in the present study and the lexical decision tasks (e.g., DiFillipo et al., 2008) require the participant to decide if the spelling of the word presented is similar to a real word, which provides a measure of spelling accuracy knowledge. There is a need to explore the spelling decision accuracy for children with and without reading impairments in order to determine if they are able to detect incorrectly spelled words in their writing. Also, to determine if the correctly spelled form of a word (i.e., homophones) is used in a given context (e.g., My mother put *their* gloves *there*.). There is a need to have intact and accurate word decoding and spelling knowledge to determine if a word presented is correctly spelled or not.

Experimental Task 3: Written Spelling

The written spelling task (experimental task 3) was conducted to answer the experimental question: was there a difference between the mean accuracy for spelling real words and nonsense words as a function of the number of syllables (1-5), or orthographic type (phonetic, nonphonetic) for fourth graders with and without reading impairments? The third experimental task included all 100 stimulus words used in Experimental Task 1. A word was presented via recording and each child was instructed to write the word they heard on a piece of lined paper. The dependent variable for the written spelling task was accuracy. The independent variables were reading group, word type, orthographic type, and word length.

Written spelling accuracy proportional means results included a significant three-way interaction for reading group, word type, and word length. The written spelling accuracy measures for the average reading group for real words (54%) and nonsense words (34%) were higher than the reading impairment group for real words (34%) and nonsense words (14%) (Figure 12). There was also a significant three-way interaction for word type, orthographic type, and word length. The written spelling accuracy results included higher accuracy for real phonetic 1 syllable words compared to the real nonphonetic, nonsense phonetic, and nonsense nonphonetic words of the same length (1 syllable). There was a linear decrease in the spelling accuracy for both word types and orthographic types with an increase in word length for the participants in this study which is similar to spelling accuracy for children between the first and fifth grades, characterized by more phonologically based errors at earlier ages (Newman, Fields, & Wright, 1993). Newman et al (1993) reported a decrease in spelling accuracy with an increase in word length for children in the fourth and fifth grades. The written spelling accuracy differences as a function of word type and orthographic type for this present study are similar to the results reported by Boder (1973; Chall, 1983; Invernizzi & Hayes, 2004; Jacobs, 2003; Leach et al., 2003; Schulte-Körne, 2010). The spelling accuracy differences found in the present study were represented by the interactions of reading group, word type, and word length and the interaction of word type, orthographic type, and word length; support the need for subtyping real and nonsense word stimuli by orthographic type and word length in the assessment and treatment of children with reading impairments.

Decoding Accuracy and Spelling Accuracy Comparisons

The research question for this study was whether an association exists between decoding accuracy and spelling accuracy for fourth-graders with and without reading impairments as a function of specific lexical parameters (word type, orthographic type, and word length) presented in a series of decoding and spelling tasks? In order to answer this question, Pearson coefficient correlations were calculated to investigate the relationship between the decoding accuracy (Experimental Task 1) and the spelling accuracy (Experimental Task 3) as a function of word type, orthographic type, and word length for the fourth graders with average reading and a primary reading impairment and are presented in Table 18.

In this study, the decoding accuracy of single words (experimental task 1) and spelling accuracy (experimental task 3) for both reading groups was impacted by the word type, orthographic type, and word length. The presence of interactions led to the rejection of the null hypothesis of no interactions. There were more 1, 2, and 3 syllable words decoded accurately compared to the 4 and 5 syllable words for both Experimental Task 1 (decoding) and Experimental Task 3 (written spelling), supporting the presence of a word length effect regardless of reading group designation, and the need for more detailed response error analysis. When considering word type differences, real word decoding accuracy and real word spelling accuracy were higher than nonsense words. Decoding and spelling accuracy was higher for phonetic words compared to nonphonetic words. There was a word length effect for both decoding accuracy and spelling accuracy resulting in more of the shorter words ($\leq$ 3 syllables) were decoded and spelled accurately compared to the longer words (4 and 5 syllables). The written spelling mean accuracy for both word types and orthographic types was characterized by a decreasing curved trend for all of the participants as a group with an increase in word length as expected. Specifically, fewer real and nonsense nonphonetic words were spelled accurately compared to real and nonsense phonetic words. The written spelling mean accuracy results of this study included more accuracy for spelling phonetic words (real and nonsense words) compared to nonphonetic words (real and nonsense words), and errors that were phonetic in nature (e.g., single consonants for clusters, vowel errors) indicated members of both reading groups are still relying on phonological information for spelling words (Gough & Walsh, 1991;

Steffler, Varnhagen, Friesen, & Treiman, 1998; Treiman, 1993; Varnhagen, Boechler, & Steffler, 1999). However, the reading impairment group's spelling words contained more errors compared to the average reading group's performance.

Clinical Implications

This study highlighted three issues that have not been explored simultaneously in an experimental study, stimuli, participants, and tasks. Speech-language pathologists and other practitioners need to critically evaluate the decoding tests they are using to assess and diagnose children with suspected reading impairments (e.g., *WRMT-III, TOWRE-2).* There is not a current and readily available standardized test that assesses both decoding and encoding (spelling) performance with similar comparative stimuli, since the *Boder Test of Reading and Spelling* (Boder & Jarrico, 1982) is out of print. The lack of a sensitive standardized assessment tool that compares stimuli subtyped by both word type and orthographic type limits the SLPs ability to make a detailed differential diagnosis of a reading impairment and plan client-specific intervention. There is a need for the use of consistent stimuli subtyped by both word type and orthographic type, this will allow for direct comparison between decoding proficiency and spelling accuracy.

The decoding accuracy for all of the real word and nonsense word stimuli (starting at item 1) which may be below the participant's current grade level should be assessed in order to determine if the participant has good decoding skills. Currently, the *WRMT-III* does not require the presentation of the real or nonsense word stimuli from the first item, as mentioned the fourth grade starting point is number 15 on the Word Identification subtest, and gives the client credit for the first 14 items even though they have not been decoded. In the *WRMT-III*, there are fewer items (average of 4) for each grade level, which limits the number of decoding opportunities that are assessed, which may inflate the standard score. It is also possible that two children may have decoded different items incorrectly and receive the same decoding raw score and decoding standard score, which limits differential diagnosis of a primary reading impairment based on decoding errors. There is a need for detailed error analysis using more than the broad category of word type (real, nonsense), because the present study results included orthographic type (phonetic, nonphonetic) differences and word length differences.

The decoding accuracy and written spelling accuracy results included significant three-interactions for word type, orthographic type, and word length supporting the need for assessment of both decoding and spelling using the same stimuli. There is one standardized assessment tool that gathers written spelling performance for only real words, the *Test of Written Spelling-5* (Larson, et al, 2013). The words used by the *TWS-5* are not separated by orthographic type, which limits differential diagnosis of spelling deficits. There is one standard score that is based on the accuracy of as few as six words (ceiling), which may all be incorrectly spelled. There are no test instructions that suggest error analysis of the incorrect items, which limits the SLPs need to conduct an error analysis. Therefore, two children will earn the same standard score by correctly spelling different words that are not categorized by orthographic type, limiting the separation of developmental errors versus atypical spelling errors (Holm, Farrier, & Dodd, 2008). Overall, in the present study, more real phonetic words were decoded and spelled accurately compared to the real nonphonetic, nonsense phonetic, and nonsense nonphonetic words respectively. The decoding accuracy and spelling accuracy performance for the participants in the present study were characterized by a linear decrease in accuracy with an increase in word length.

Participants

A heterogeneous group of fourth-graders, between the ages of 9;0 and 11;10 years of age participated in the present study. The participants were grouped using standardized scores on the *WRMT-III,* which provided broad real word decoding and nonsense word decoding performance. The lack of item subtyping by orthographic type limits the comparison between the pre-experimental decoding tasks and the experimental tasks for the present study. Additional item analyses using orthographic categories will provide more detail for the subtyping of the children in the reading impairment group. It is likely that there is also variation with the average reading group dependent on the correct items used to determine the standard score. Spelling accuracy differences were present for the participant in this study. Two of the members of the average reading group had below average spelling performance, and three members of the reading impairment group had below average spelling performance according to the standard score obtained on the *TWS-5,* which was not expected. Additional item-based analysis of the accurately spelled words may provide more detailed classification for this group of participants.

The use of the same stimuli categorized by word type, orthographic type, and word length in the experimental tasks in this study provided more detailed information than the pre-experimental task results. It is easier to compile a decoding accuracy, spelling decision, and spelling accuracy based profile for each participant. It is easier to provide each participant's parents and teachers with current single word decoding and spelling information that may be used to determine the areas of strength and weakness to guide child-specific instruction. The same information for the children in the reading impairment group may also be shared with the school-based SLP if the parent is concerned about their child's reading and spelling performance.

Limitations

It is important to discuss the limitations of this study: participants (small number and uneven distribution of groups), stimulus conditions, detailed analyses. First it would have been ideal to have more than 23 participants in this study, with an equal number of participants in the Average Reading Group and the Reading Impairment Group. A larger number of participants would have allowed for subtyping the children who were classified in the reading impairment group into dyseidetic (poor sight-word decoding and spelling), dysphonetic (poor phonological decoding and spelling), and mixed (combination of poor sight-word and phonological decoding and bizarre spelling) (Boder, 1973) reading impairments using the pre-experimental test performance. Having three subtyped groups within the reading impairment group would have allowed for comparison between the groups and may have provided more research-based information that may be used for diagnostic and invention purposes.

The second limitation of this study was a comprehensive speech and language battery was not completed for all participants. The focus of this study was on decoding accuracy and spelling accuracy, so only a few standardized tests were used. It would be advantageous for additional speech and language testing to be completed for all of the participants from this study in order to determine if there are additional deficit areas that may negatively impacting single word decoding and written spelling performance.

The third limitation of this study was the length of the time allowed for the response (2,000 ms). All of the participants reported that the time was too short for them to provide accurate responses, specifically for the longer words (4 and 5 syllable) for the decoding and spelling decision tasks. It is possible that there may have been more correct responses for the two longest word lengths given more time. The use of a 5,000 ms time limit for each item may be considered in future research studies to allow for comparison using the same stimuli and age group, with a longer opportunity to respond. The increased time available may result in higher decoding accuracy, since there were some incorrect and non-responses due to the short time limit for participants in both reading groups.

The fourth limitation of this study was the lack of inter- and intra-rater reliability analyses. Reliability analyses for the decoding accuracy, spelling decision accuracy, and written spelling accuracy were not completed for this study and should be conducted in order to provide more detailed information. Also inter-rater reliability information, specifically for the written spelling accuracy may provide additional information related to the types of errors that are present in this study, which may benefit future research in the area of spelling. If there are differences in the decoding accuracy between raters, there would be additional support for the need for a standardized decoding and spelling assessment tool to be developed for use by SLPs and other professionals for the diagnosis and treatment of children and adults with and without reading impairments.

Detailed error analyses for both the correct and incorrect decoding and written spelling responses for all real word and nonsense word stimuli by word type and orthographic type for all three experimental tasks should be completed in order to determine if there trends for specific stimuli. Also, more detailed analysis using the word frequency (high, low) would provide information concerning the presence or absence of an effect on the decoding and written spelling accuracy results for each word used in this study. Also, detailed spelling error analysis would provide information concerning specific developmental spelling patterns for each word, participant that would benefit future researchers, SLPs, and other professionals.

A comparison between the task accuracy for the decoding accuracy and written spelling accuracy for each real word and nonsense word should be conducted to determine whether there were differences in the accuracy for each word between the tasks for all stimuli. Specifically, whether there was a difference in the decoding accuracy and written spelling accuracy as a function of the word itself. For example, whether the word "does" was decoded more accurately than it was spelled accurately for each individual. It is possible that lower decoding for one word of the five possible for each word length had a significant impact on the overall proportional mean which biased the results of this study. It is also possible that there were differences between the decoding accuracy and written spelling accuracy within the individual that impacted the results of this study.

Finally, detailed profile analyses for each participant should be conducted in order to determine whether there is a trend in the differences in decoding accuracy and spelling accuracy that may be used as the basis for future research. Item-by-item analyses between the pre-experimental test stimuli and the experimental task stimuli used in this study should be conducted to determine if there is a difference as a function of orthographic type.

Future Research

Future research using the current study's methods and stimuli may provide SLPs with a more comprehensive assessment tool to identify the developmental stage for each child evaluated based on detailed decoding information, and detailed spelling abilities, and strengths and weaknesses that may be used to make a differential diagnosis and for planning of focused child-specific intervention. Replication of the current study with both younger children (2^{nd} and 3^{rd} graders), older children (5^{th} to 9^{th} grade), and adults in Eastern North Carolina and other states would benefit the field of speech language pathology. There is variation in the characteristics of children who are referred for assessment with reading difficulties, so the inclusion of children who are English Language Learners, children with developmental speech and language delays, children with Autism, and children and adults with developmental disabilities may provide insight into the decoding and spelling similarities and differences when compared to the participants in this study. The data from the proposed future research may provide vital information for the development of a comprehensive assessment protocol that is research-based, current, efficient, and cost effective.

References

Aaron, P.G. (1991). Can reading disabilities be diagnosed without using intelligence tests? *Journal of Learning Disabilities, 24,* 178-186.

American Speech-Language-Hearing Association. (1997). *Guidelines for audiologic screening* [Guidelines]. Available from www.asha.org/policy. doi:10.1044/policy.GL1997-00199

American Speech-Language-Hearing Association. (2001). *Roles and responsibilities of speech-language pathologists with respect to reading and writing in children and adolescents* [Guidelines]. Available from www.asha.org/policy. doi:10.1044/policy.GL2001-00062

American Association of University Women Educational Foundation (1992). *How School Shortchange Girls.* Washington, DC: Author.

Ans, B., Carbonnel, S., & Valdois, S. (1998). A connectionist multiple-trace memory model for polysyllabic word reading. *Psychological Review*, *105*(4), 678-723.

Audacity Development Team. (n.d.). *About Audacity.* Available at: http://audacity.sourceforge.net/

Bailet, L. L., & Lyon, G.R., (1985). Proficient linguistic rule application in a learning disabled speller: A case study. *Journal of Learning Disabilities, 18*(3), 162-164.

Bååth, R. (2010). ChildFreq: An online tool to explore word frequencies in child language. LUCS Minor, *16.* ISSN 1104-1609. Available at: http://childfreq.sumsar.net/faq

Balota, D.A., Cortese, M.J., Sergent-Marshall, S.D., Spieler, D. H., Yap, M.J. (2004). Visual word recognition of single-syllable words. *Journal of Experimental Psychology: General, 133*(2), 283-316. doi: 10.1037/0096-3445.133.2.283

Balota, D.A., Yap, M.J., Cortese, M.J., Hutchison, K.A., Kessler, B., Loftis, B., Neely, J.H., Nelson, D.L., Simpson, G.B., & Treiman, R. (2007). The English Lexicon Project. *Behavior Research Methods, 39,* 445-459.

Barry, C. (1994). In G. Brown & N. Ellis (Eds.), *Handbook of spelling: Theory, process and intervention.* Chichester: Wiley.

Bear, D.R. (1992). The prosody of oral reading and stages of word knowledge. In S. Templeton and D.R. Bear, (Eds.). *Development of Orthographic Knowledge and the Foundations of Literacy,* Newark, DE: International Reading Association.

Bergman, C. (2006). Reading development: Letter by letter decoding in English and Italian readers. *Intel Science Talent Search.* Retrieved on May 22, 2013 from http://psych.nyu.edu/pelli/highschool.html#2006

Bergmann, J., Hutzler, F., Klimesch, W., & Wimmer, H. (2004). How is dysfluent reading reflected in the ERP? *Journal of Neurolinguistics, 18,*153-165. doi: 10.1016/j.jneuroling.2004.11.004

Boder, E. (1969). Developmental dyslexia: A diagnostic screening procedure based on reading and spelling patterns. *Intervention in School and Clinic, 4*, 285.doi: 10.1177/105345126900400408.

Boder, E. (1973). Developmental dyslexia: A diagnostic approach based on three atypical reading-spelling patterns. *Developmental Medical Child Neurology, 15,* 663-687. doi: 10.1111/j.1469-8749.1973.tb05180.x

Boder, E., & Jarrico, S. (1982). *Boder Test of Reading/ Spelling Patterns: Diagnostic Screening Test for Subtypes of Reading Disability*. New York, NY: Grune & Stratton, Inc.

Booth, J.R., Cho, S., Burman, D.D., & Bitan, T. (2007). Neural correlates of mapping from phonology to orthography in children performing an auditory spelling task. *Developmental Science, 10*(4), 441-451.

Bosman, A.M.T., & Van Orden, G.C. (1997). Why spelling is more difficult than reading. In C.A. Perfetti, R. Rieben, & M. Fagol (Eds.), *Learning to spell. Research, theory, and practice across languages* (pp. 173–194). London: Erlbaum.

Bourassa, D., & Treiman, R. (2003). Spelling in dyslexic children: Analyses from the Treiman-Bourassa Early Spelling Test. *Scientific Studies of Reading, 7,* 309-333.

Bourassa, D.C., & Treiman, R. (2008). Morphological constancy in spelling: A comparison of children with dyslexia and typically developing children. *Annals of Dyslexia, 14,* 155-169. doi: 10.1002/dys.368.

Bruck, M., & Treiman, R. (1990). Phonological awareness and spelling in normal children and dyslexics: The case of initial consonant clusters. *Journal of Memory & Language*, *45*(4), 751–775.

Caravolas, M., Hulme, C., & Snowling, M.J. (2001). The foundations of spelling ability: Evidence from a 3-year longitudinal study. *Journal of Memory and Language, 45*, 751-774.

Castles, A., & Coltheart, M. (1993). Varieties of developmental dyslexia. *Cognition, 47*, 149-180.

Catani, M. & ffytche, D.H. (2005). The rises and falls of disconnection syndromes. *Brain, 128,* 2224-2239. doi: 10.1093/brain/awh622

Cedrus Corporation (2014). Super Lab 5 [computer software]. San Pedro, CA. Available from www.superlab.com

Chall, J. (1983). *Stages of reading development*. New York, N.Y.: McGraw-Hill.

Chall, J.S. and Jacobs, V.A. (2003). Poor children's fourth-grade slump. *American Educator*, Spring, 2003. Retrieved September 9, 2013, from http://www.aft.org/pubs-reports/american_educator/spring2003/chall.html.

Chilosi, A.M., Brizzolara, D., Lami, L., Pizzoli, C., Gasperini, …. (2009). Reading and spelling disabilities in children with and without a history of early language delay: A neuropsychological and linguistic study. *Child Neuropsychology, 15,* 582-604. doi: 10.1080/09297040902927614

Clarke-Klein, S., & Hodson, B.W. (1995).A phonologically based analysis of misspellings by third graders with disordered-phonology histories. *Journal of Speech and Hearing Research, 38,* 839-849.

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: a dual route cascaded model of visual word recognition and reading aloud, *Psychological Review, 108*(1), 204-256.

Coltheart, M. (2005). Modeling Reading: The dual-route approach. In M.J. Snowling & C. Hulme (Eds.), *The science of reading: A handbook* (pp. 6-23). Oxford: Blackwell.

Cook, J.L., & Cook, G. (2009). *Child development principles and perspectives*-Second Edition, (pp. 246-250). San Antonio, TX: Pearson.

Corballis, M.C., Hattie, J., & Fletcher, R. (2008).Handedness and intellectual achievement: An even-handed look. *Neuropsychologia*, 46(1), 374-378.

Cordenwener, K.A.H., Bosman, A.M.T., & Verhoeven, L. (2012). Predicting early spelling difficulties in children with specific language impairment: A clinical perspective. *Research in Developmental Disabilities*, *33*, 2279-2291. http://dx/doi.org/10.1016/j.ridd.2012.07.003

Council on Scientific Affairs (1989). Dyslexia. *Journal of the American Medical Association, 261*(15), 2236–2239.

Curtin, S., Manis, F. R., & Seidenberg, M. S. (2001). Spelling errors in subtypes of developmental dyslexia. *Reading and Writing: An Interdisciplinary Journal*, *14*, 521-554.

Davies, M. (2010). English word frequency, collocates, and n-grams. [database]. Available at: http://www.wordfrequency.info/

DeFries, J. C., & Alarcon, M. (1996). Genetics of specific reading disability. *Mental Retardation Developmental Disabilities Research Review*, *2*(1), 39–47.

DeLuca, M., Barca, L., Burani, C., Zoccolotti, P. (2008). The effect of word length, and other sublexical, lexical, and semantic variables on developmental reading deficits. *Cognitive Behavioral Neurology, 21*(4), 227-235. doi: 10.1097/WNN.0b013e318190d162.

DeMaster, V.K., Crossland, C.L., & Hasselbring, T.S. (1986). Consistency of learning disabled students' spelling performance. *Learning Disability Quarterly, 9,* 89-96.

Denton, K., Reaney, L., & West, J. (2001). *Home educational activities, literacy resources and kindergartners' reading knowledge and skills*. Presentation at the biennial meeting of the Society for Research in Child Development, Minneapolis, MN.

DiFillippo, G., DeLuca, M., Judica, A.., Spinelli, D., & Zoccolotti, P. (2006). Lexicality and stimulus length effects in Italian dyslexics: Role of the overadditivity effect. *Child Neurophsychology, 12,* 141-149. doi: 10.1080/09297040500346571

Duncan, L.G., & Seymour, P.H.K. (2003). How do children read multisyllabic words? Some preliminary observations. *Journal of Research in Reading, 26*(2), 101-120.

Dunn, L.M., & Dunn, D.M. (1997). *Peabody Picture Vocabulary Test*-Fourth Edition. San Antonio, TX: Pearson

Eckert, M. (2004). Neuroanatomical markers for dyslexia: A review of dyslexia structural imaging studies. *Neuroscientist,10,* 362-371.

Educational Alliance (2007).*Gender Differences in Reading Achievement: Policy Implications and Best Practices*. Publisher: Charleston, WV. Retrieved on May 1, 2014 from http://www.educationalliance.org/files/Gender-Differences.pdf

Ehri, L.C. (1995). Phases of development in learning to read words by sight. *Journal of Research in Reading, 18*(2), 116-125.

Eisenmajer, N., Ross., N., & Pratt, C. (2005). Specificity and characteristics of learning disabilities. *Journal of Child Psychology and Psychiatry, 46,* 1108–1115.

Elbro, C. (1996). Early linguistic abilities and reading development. *Reading and Writing: An Interdisciplinary Journal, 8,* 453-485.

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

Ellis, A.W., & Young, A.W. (1988).*Human Cognitive Neuropsychology*. Hove, East Sussex: Lawrence Erlbaum.

Fernald, G. (1943). *Remedial Techniques in Basic School Subjects.* New York, NY: McGraw Hill.

Fien, H., Park, Y., Baker, S. K., Smith, J. L. M., Stoolmiller, M., & Kame'enui, E. J. (2010). An examination of the relation of nonsense word fluency initial status and gains to reading outcomes for beginning readers. *School Psychology Review, 39,* 631–653.

Flynn, J.M., & Rahbar, M.H. (1994). Prevalence of reading failure in boys compared with girls. *Psychology in the Schools, 31*(1), 66–71.

Forrester, G.S., Pegler, R., Thomas, M.S.C., & Mareschal, D. (2014). Handedness as a marker of cerebral lateralization in children with and without autism. *Behavioural Brain Research, 268,* 14-21.

Forster, K., & Chambers, S. (1973). Lexical access and naming time. *Journal of Verbal Learning and Verbal Behavior*, *12,* 627-635.

Frasch, D.K. (1965). How Well Do Sixth-Graders Proofread for Spelling Errors? *The Elementary School Journal*, *65*(7), 381-385.

Friend, A., & Olson, R.K. (2010). Phonological spelling and reading deficits in children with spelling disabilities. *Scientific Study of Reading, 12*(1), 90-105. doi: 10.1080/10888430701773876.

Frith, U. (1986). A developmental framework for developmental dyslexia. *Annals of Dyslexia, 36,* 69-81.

Fry, E. (2000). *1,000 Instant Words Most Common Words for Teaching Reading.* Westminster, CA: Teacher Created Resources.

Gagnepain, P., Henson, R.N., & Davis, M.H. (2012). Temporal predictive codes for spoken words in auditory cortex. *Current Biology.* 22, 615–621.

Gannon, P.J., Kheck, N.M., Braun, A.R., & Halloway, R.L. (2005). Planum parietale of chimpanzees and orangutans: A comparative resonance of human-like planum temporale asymmetry. *The Anatomical Record Part A,* 287A, *1128-1141.*

Gannon, P. J., Kheck, N. M., Braun, A. R., & Holloway, R. L. (2005). Planum parietale of chimpanzees and orangutans: A comparative resonance of human-like planum temporale asymmetry. *Anatomical Record, 287A,* 1128–1141. doi: 10.1002/ar.a.20256

Ganske, K. (1999). The developmental spelling analysis: A measure of orthographic knowledge. *Educational Assessment*, *6*(1), 41-70.

Gathercole, S. E., Willis, C. S., & Baddeley, A. D. (1991). Differentiating phonological memory and awareness of rhyme: Reading and vocabulary development in children. *British Journal of Psychology, 82*, 387–406.

Gathercole, S.E., Willis, C.S., Baddeley, A.D., & Emslie, H. (1994). The children's test of nonword repetition: A test of phonological working memory. *Memory*, *2*(2), 103-127.

Gentry, J.R. (1982). An analysis of development spelling in GYNS AT WRK. *The Reading Teacher*, *36*(2), 192-200.

Geva, E., Wade-Woolley, L., & Shany, M. (1993). The concurrent development of spelling and decoding in two different orthographies. *Journal of Reading Behavior, 25*(4), 383-406.

Good, R. H., & Kaminski, R. A. (Eds.). (2002). Dynamic Indicators of Basic Early Literacy Skills (6th ed.). Eugene, OR: Institute for the Development of Educational Achievement. Available: http://dibels.uoregon.edu/.

Goodman, K. (1967). "Reading: A Psycholinguistic Guessing Game." *Journal of the Reading Specialist*, 6(4), 126-135.

Goswami, U., & Bryant, P.E. (1990). *Phonological Skills and Learning to Read*. London: Erlbaum.

Gough, P. (1972). One second of reading. In J.F. Kavanagh & I.G. Mattingly (Eds.), *Language by ear and by eye. (*pp.691-697). Cambridge, MA: MIT Press.

Greenberg, D., Ehri, L.C., & Perin, D. (1997). Are word-reading processes the same or different in adult literacy students and third-fifth graders matched for reading level? *Journal of Educational Psychology, 89*(2), 262-275.

Hall-Mills, S. & Apel, K. (2011). Differential effects of letter-name spelling and text representation on early reading ability. *Contemporary Issues in Communication Science and Disorders, 38,* 97-108. doi: 1092-5171/11/3802-0097

Handler, S.M., Fierson, W.M., & Section on Opthalmology and Council Learning Disabilities, Dyslexia, and Vision. (2011). Joint Technical Report—Learning Disabilities, Dyslexia, and Vision. *Pediatrics, 127,* e818-e856. doi: 10.1542/peds.2010-3670

Henderson, E.H., & Templeton, S. (1986). A developmental perspective of formal spelling instruction through alphabet, pattern, and meaning. *The Elementary School Journal, 86*(3), 305-316.

Holm, A., Farrier, F., & Dodd, B. (2008). Phonological awareness, reading accuracy and spelling ability of children with inconsistent phonological disorder. *International Journal of Language and Communication Disorders, 43*(3), 300-322.

Holmes, V.M., & Babauta, M.L. (2005).Single or dual representations for reading and spelling? *Reading and Writing, 18,* 257–280.

Hornickel, J., Skoe, E., & Kraus, N. (2009). Subcortical laterality of speech encoding. *Audiology and Neurology, 14,* 198-207. doi: 10.1159/000188533

Horst, J. S., Parsons, K.L., & Bryan, N.M. (2011). Get the story straight: contextual repetition promotes word learning from storybooks. *Frontiers in Psychology, 2*(17), 1-11. doi: 10.3389/fpsyg.2011.00017

Houghton, G., & Zorzi, M. (2003). Normal and impaired spelling in a connectionist dual-route architecture. *Cognitive Neuropsychology, 20,*115–162.

International Dyslexia Association (2002). *Definition of dyslexia*. Downloaded on January 12, 2012 from http://www.interdys.org/FAQWhatIs.htm

International Dyslexia Association (2003). *Nonword Decoding Test.* Downloaded March 3, 2014 from http://www.dyslexia-international.org/content/Informal%20tests/Nonword decodingtest.pdf

Invernizzi, M., & Hayes, L. (2004). Developmental-spelling research: A systematic imperative. *Reading Research Quarterly, 39*(2), 216-228.

Invernizzi, M., & Worthy, M.J. (1989). An orthographic-specific comparison of the spelling errors of learning disabled and normal children across four grade levels of spelling achievement. *Reading Psychology: An International Quarterly, 10*, 173-188.

Irwin, J. (1986). *Teaching Reading Comprehension Processes.* Upper Saddle River, NJ: Prentice Hall.

Jäncke, L., Schlaug, G., Huang, Y., & Steinmetz, H. (1994). Asymmetry of the planum parietale. *Neuroreport, 5*, 1161–1163.

Jastak, J.F., & Jastak, S. (1978). *Wide Range Achievement Test.* Lutz, FL: Psychological Assessment Resources.

Kena, G., Aud, S., Johnson, F., Wang, X., Zhang, J., Rathbun, A., Wilkinson-Flicker, S., and Kristapovich, P. (2014). *The Condition of Education 2014* (NCES 2014-083). U.S. Department of Education, National Center for Education Statistics. Washington, DC. Retrieved July 8, 2014 from http://nces.ed.gov/pubsearch.

Kučera, H., & Francis, W. (1967). *Computational analysis of present-day American English.* Providence, RI: Brown University Press.

LaBerge, D., & Samuels, S. J. (1974). Toward a theory of automatic information processing in reading. *Cognitive Psychologist*, 6, 293-323.

Larsen, S.C., Hammill, D., & Moats, L. (2013). *Test of Written Spelling*-Fifth Edition. Austin, TX: Pro-Ed.

Leonard, C.M., & Eckert, M.A. (2008). Asymmetry and dyslexia. *Developmental Neuropsychology*, *33*, 663-681.

Leach, J. M., Scarborough, H.S., & Rescorla, L. (2003). Late-emerging reading disabilities. *Journal of Educational Psychology*, *9*(2), 211-224.

Leonard, C. M., Voeller, K. K. S., Lombardino, L. J., Morris, M. K., Hynd, G. W., Alexander, A. W., Anderson, H. G., Garofalakalis, M., Honeyman, J. C., Mao, J., Agee, F., & Staab, E. V. (1993). Anomalous cerebral structure in dyslexia revealed with magnetic resonance imaging. *Archives of Neurology, 50*, 461-469.

Lutz, E. (1986). ERIC/RCS Report: Invented Spelling and Spelling Development. *Language Arts*, *63*(7), 742-744.

Lyle, K.B., McCabe, D.P., & Roediger III, H.L. (2008). Handedness is related to memory via hemispheric interaction: Evidence from paired associate recall and source memory tasks. *Neuropsychology*, *22*(4), 523-530.

Lyon, G.R. (1996). Learning disabilities. *Future Child. 6*(1), 54–76.

Lyon, G.R., (1997). Report on learning disabilities research. Available at www.ldonline.org/article/6339.Accessed on June 17, 2013

Lyon, G.R., (1998). Statement of Dr. G. Reid Lyon. Available at: www.dys-add.com/ ReidLyonJeffords.pdf. Accessed June 17, 2013.

Martin, A., Wiggs, C.L., LaLonde, F., & Mack, C. (1994). Word retrieval to letter and semantic cues: A double dissociation in normal subjects using interference tasks. *Neuropsychologia, 32*(12), 1487-1494.

Masterson, J.J., & Apel, K. (2010). The spelling sensitivity score: Noting developmental changes in spelling knowledge. *Assessment for Effective Intervention, 36*(1), 35-45.

Maughan, B., Messer, J., Collishaw, S., Pickles, A., Snowling, M., & Rutter, M. (2009). Persistence of literacy problems: Spelling in adolescence and at mid-life. *Journal of Child Psychology and Psychiatry*, *50*(8), 892-901.

Moats, L.C. (1993). Spelling error interpretation: Beyond the phonetic/dysphonetic dichotomy. *Annals of Dyslexia*, *43,* 174-185.

Moats, L.C. (2005). How spelling supports reading: And why it is more regular and predictable than you think. *American Educator,* Winter 2005/06, 12-22, 42-43.

Moll, K., & Landerl, L. (2009). Double dissociation between reading and spelling, *Scientific Studies of Reading,* 13(5), 359-382.

Morton, J. (1980). The logogen model and orthographic structure. In Frith, U. (Ed.), *Cognitive Processes in Spelling*. (pp. 259-268). London: Academic Press.

National Institute of Neurological Disorders and Stroke (2010). *Dyslexia Information Page.* Retrieved from http://www.ninds.nih.gov/disorders/dyslexia/dyslexia.htm. July, 2010.

Nazir, T.A., Ben-Boutayab, N., Decoppet, N., Deutsch, A., & Frost, R. (2004). Reading habits, perceptual learning, and recognition of printed words. *Brain and Language, 88*, 294-311.

New, B., Ferrand, L., Pallier, C., & Brysbaert, M. (2006). Reexamining the word length effect in visual word recognition: New evidence from the English Lexicon Project. *Psychonomic Bulletin & Review 13*(1), 45-52.

Newman, S., Fields, H., & Wright, S. (1993). A developmental study of specific spelling disability. *British Journal of Educational Psychology, 63,* 287-296.

Newman, S., Malaia, E., & Seo, R. (2014). Does degree of handedness in a group of right-handed individuals affect language comprehension? *Brain and Cognition, 86*, 98-103.

Nicholson, T., Bailey, J., & McArthur, J. (1991). Context cues in reading: The gap between research and popular opinion. *Reading, Writing, and Learning Disabilities, 7,* 33-41.

O'Regan, J.K., & Jacobs, A.M. (1992). Optimal viewing position effect in word recognition: A challenge to current theory. *Journal of Experimental Psychology: Human Perception and Performance, 18*(1), 185-197.

Paulesu, E., Frith, U., Snowling, M., Gallagher, A., Morton, J., & Frackowiak, R.S. (1996). Is developmental dyslexia a disconnection syndrome? Evidence from PET scanning. *Brain, 119,* 143–57.

Pennington, B.F. (1999). Toward an integrated understanding of dyslexia: genetic, neurological, and cognitive mechanisms. *Developmental Psychopathology, 11*(3), 629–654.

Pennington, M. (2009). How to teach sight words. Downloaded on June 22, 2014 from http://penningtonpublishing.com/blog/reading/how-to-teach-sight-words/.

Perfetti, C., Rieben, L., & Fayol, M. (Eds.). (1997). *Learning to Spell: Research, Theory, and Practice Across Languages*. Mahwah, NJ: Lawrence Erlbaum and Associates.

Peterson, G., Patton, J.E., Mills, J., Gabe, R., McBride, R., & Wanat, C. (1999). Educator's judgments of children's spelling errors as predictors of reading disability. Paper presented at the Annual Convention of the National Association of School Psychologists (Las Vegas, NV, April 6-10, 1999).

Plaut, D.C., McClelland, J.L., Seidenberg, M.S., & Patterson, K. (1996). Understanding normal and impaired word reading: Computational principles in quasi-regular domains. *Psychological Review, 103*(1), 56-115.

Psychological Corporation. (1984). *Stanford Diagnostic Reading Test.* San Antonio, TX: Psychological Corporation.

Rack, J., Snowling, M., & Orton, T. (1992). The nonword reading deficit in developmental dyslexia: A review. *Reading Research Quarterly, 27*, 29-53.

Rapcsak, S.Z., Henry, M.L., Teague, S.L., Carnahan, S.D., & Beeson, P.M. (2007). Do dual-route models accurately predict reading and spelling performance in individuals with acquired alexia and agraphia? *Neuropsychologia, 45*(11), 2519-2524. doi: 10.1016/j.neuropsychologia.2007.03.019

Rastle, K. & Coltheart, M. (2000). Lexical and nonlexical print-to-sound translation of disyllabic word and nonwords. *Journal of Memory and Language, 42,* 342-364.

Raven, J.C. (1976). *Raven's Progressive Coloured Matrices.* San Antonio, TX: Pearson.

Rescorla, L. (1989). The language development survey: A screening tool for delayed language in toddlers. *Journal of Speech and Hearing Disorders, 54*(4), 587-599. doi:10.1044/jshd.5404.587

Rice, M. L., Huston, A. C., Truglio, R., & Wright, J. (1990).Words from Sesame Street: Learning vocabulary while viewing television. *Developmental Psychology*, 26, 421–428.

Rice, M. L., & Woodsmall, L. (1984). Lessons from television: Children; word learning when viewing. *Child Development*, 59, 420–429.

Rimrodt, S.L., & Lipkin, P.H. (2011). Learning disabilities and school failure. *Pediatrics in Review, 32*(8), 315-324. doi: 10.1542/pir.32-8-315.

Rispens, J. (1990). Comprehension Problems in Dyslexia. In D.A. Balota, G.B. Flores d'Arcais, and K. Rayner (Eds.), *Comprehension Processes in Reading* (pp. 603-620). Mahwah, NJ: Lawrence Erlbaum Associates.

Rubenstein, H.H., Lewis, S.S., & Rubenstein, M.A. (1971). Evidence for phonemic recoding in visual word recognition. *Journal of Verbal Learning and Verbal Behavior, 10*, 645-657.

Rumelhart, D.E. (1975). Notes on a schema for stories. In D.G. Bobro & A.M. Collins (Eds.), *Representation and understanding: Studies in cognitive science.* New York, NY: Academic Press.

Samuels, S.J. (1979). The method of repeated readings. *The Reading Teacher, 32*(4), 403-408.

Schulte-Korne, G. (2010). The prevention, diagnosis, and treatment of dyslexia. (C. Devitt, Trans.). *Deutsches Arzteblatt International, 107*(41), 718-727. doi: 10.3238/arztebl.2010.0718

Scuccimarra, G., Cutolo, L., Fiorillo, P., Lembo, C., et al. (2008). Is there a distinct form of developmental dyslexia in children with specific language impairment? Findings from an orthographically regular language. *Cognitive and Behavioral Neurology, 21*(4), 221-226.

Seymour, P.H.K., & MacGregor, J. (1984). Developmental dyslexia: A cognitive experimental analysis of phonological, morphemic, and visual impairments. *Cognitive Neuropsychology, 1*(1), 43-82.

Shaul, S., Arzouan, Y., & Goldstein, A. (2012). Brain activity while reading words and pseudowords: A comparison between dyslexic and fluent readers. *International Journal of Psychophysiology, 84*, 270-276. doi: 10.1016/j.ijpsycho.2012.03.005

Shaywitz, S.E. (1996) Dyslexia. *Scientific American, 275*(5), 98–104.

Shaywitz, S.E. (1998). Dyslexia. *New England Journal of Medicine. 338*(5), 307–312.

Shaywitz, S.E. (2003). Overcoming dyslexia: A new and complete science-based program for overcoming reading problems at any level. New York, NY: Knopf.

Shaywitz, S.E., & Shaywitz, B.A. (2003). The science of reading and dyslexia. *Journal of AAPOS, 7*(3), 158–166.

Shaywitz, S.E., & Shaywitz, B.A. (2005). Dyslexia (specific reading disability). *Biological Psychiatry, 57*(11), 1301-1309.

Shaywitz, S.E., & Shaywitz, B.A. (2007).The neurobiology of reading and dyslexia. Available at: www.ncsall.net/?id 278. Accessed June 17, 2013 and *ASHA Leader* (2007). Retrieved from http://www.asha.org/Publications/leader/2007/070904/070904f.htm.

Shaywitz, S.E., Shaywitz, B.A., Fletcher, J.M., Escobar, M.D. (1990). Prevalence of reading disability in boys and girls: Results of the Connecticut Longitudinal Study. *Journal of the American Medical Association, 264*(8), 998–1002.

Siegel, L.S., & Ryan, E.B. (1989). Subtypes of developmental dyslexia: The influence of definitional variables. *Reading and Writing: An Interdisciplinary Journal, 2*, 257-287.

Silliman, E.R., Bahr, R.H., & Peters, M.L. (2006). Spelling patterns of preadolescents with atypical language skills: Phonological, morphological, and orthographic factors. *Developmental Neuropsychology, 29*(1), 93-123.

Simon, D.P., & Simon H.A. (1973). Alternative uses of phonemic information in spelling. *Review of Educational Research, 43,* 115-137.

Smith, F. (1971). *Understanding reading*. New York: Holt, Rinehart & Winston.

Snow, C.E., Burns, M.S., & Griffin, P. (Eds.) (1998). *Preventing Reading Difficulties in Young Children.* Washington, DC: National Academy Press.

Snowling, M.J. (1985). *Children's Written Language Difficulties.* Windsor: NFER-Nelson.

Snowling, M. J. (2001), From language to reading and dyslexia. Dyslexia, 7: 37–46. doi: 10.1002/dys.185

Speece, D.L., Rothe, F.P., Cooper, D.H., & De La Paz, S. (1999). The relevance of oral language skills to early literacy: A multivariate analysis. *Applied Psycholinguistics, 20,* 167-190.

Spinelli, D. et al. (2005). Length Effect in Word Naming in Reading: Role of Reading Experience and Reading Deficit in Italian Readers. *Developmental Neuropsychology, 27*(2), 217-235. doi:10.1207/s15326942dn2702_2

Steacy, L.M. (2009). Timing is everything: Early identification and the double deficit hypothesis. Thesis submitted to Queen's University, Kingston, Ontario, Canada.

Stevenson, J., Graham, P., Fredman, G., & McLoughlin, V. (1987). A twin study of genetic influences on reading and spelling ability and disability. *Journal of Child Psychology and Psychiatry, 28*(2), 229-247.

Stevenson, J., Langley, K., Pay, H., Payton, A., Worthington, J., Ollier, W., & Thapar, A. (2005). Attention deficit hyperactivity disorder with reading disabilities: Preliminary genetic findings on the involvement of the ADRA2A gene. *Journal of Child Psychology and Psychiatry, 46*(10), 1081-1088.

Tainturier, M-J., & Rapp, B. (2001). The spelling process. In B. Rapp (Ed.). *The Handbook of Cognitive Neuropsychology: What Deficits Reveal about the Human Mind*, pp. 263-289. Philadelphia: Psychology Press.

Templeton, S., & Bear, D.R. (1992). *Development of Orthographic Knowledge and the Foundations of Literacy: A Memorial Festschrift for Edmund H. Henderson.* Mahwah, NJ: Lawrence Erlbaum and Associates

Thaler, V., Landerl, K., & Reitsma, P. (2008). An evaluation of spelling pronunciations as a means of improving spelling of orthographic markers. *European Journal of Psychology of Education, XXIII*(1), 3-23.

Thorndike, E.L. & Lorge, I. (1944). *The teacher's word book of 30,000 words.* Teachers College, Columbia University, 1944.

Toga, A.W., & Thompson, P.M. (2003). Mapping brain asymmetry. *Nature Reviews Neuroscience, 4,* 37-48.

Torgeson, J.K. (1998). Catch them before they fail: Identification and assessment to prevent reading failure in young children. *American Educator.* Available at: www.aft.org/pdfs/americaneducator/springsummer1998/torgeson.pdf. Accessed June 17, 2013.

Torgeson, J.K. (1999). Assessment and instruction for phonemic awareness and word recognition skills. In H.W. Catts & A.G. Kamhi (Eds.), *Language and reading disabilities* (pp.128-149). Needham Heights, MA: Allyn & Bacon.

Treiman, R., & Bourassa, D. (2000). Children's written and oral spelling. *Applied Psycholinguistics, 21,* 183-204.

Van den Broeck, W., & Geudens, A. (2012). Old and new ways to study characteristics of reading disability: The case of the nonword-reading deficit. *Cognitive Psychology, 65*(3), 414-456. doi: 10.1016/j.cogpsych.2012.06.003

van Ijzendoorn, M., & Bus, A. (1994). Meta-analytic confirmation of the nonword reading deficit in developmental dyslexia. *Reading Research Quarterly, 29,* 266-275.

Vellutino, F.R., Fletcher, J.M., Snowling, M.J., & Scanlon, D.M. (2004). Specific reading disability (dyslexia): what have we learned in the past four decades? *Journal of Child Psychology and Psychiatry*, *45*(1), 2–40.

Walker, M. M., Spires, H., & Rastatter, M. P. (2001). Hemispheric processing characteristics for lexical decisions in adults with reading disorders. *Perceptual and Motor Skills,* 92, 273-287.

Waters, G.S., Bruck, M., & Seidenberg, M. (1985). Do children use similar processes to read and spell words? *Journal of Experimental Psychology, 39,*511-530.

Woodcock, R.W. (1998). *Woodcock Reading Mastery Tests*-Revised. San Antonio, TX: Pearson.

Woodcock, R.W. (2011). *Woodcock Reading Mastery Tests,* Third Edition. San Antonio, TX: Pearson.

Worthy, M.J., & Invernizzi, M. (1990). Spelling errors of normal and disabled students on achievement levels one through four: Instructional implications. *Annals of Dyslexia,40,* 138-151.

Young, K. (2007). Developmental stage theory of spelling: Analysis of consistency across four spelling-related activities. *Australian Journal of Language and Literacy, 30*(3), 203-220.

Zadina, J.N., Corey, D.M., Casbergue, R.M., Lemen, L.C., Rouse, J.C., Knaus, T.A., & Foundas, A.L. (2006). Lobar asymmetries in subtypes of dyslexic and control subjects. *Journal of Child Neurology, 21*, 922-931.

Zeno, S. M., Ivens, S. H., Millard, R. T., & Duvvuri, R. (1995). *The educator's word frequency guide.* Brewster, NY: Touchstone Applied Science.

Ziegler, J.C., & Goswami, U. (2005). Reading acquisition, developmental dyslexia, and skilled reading across languages: a psycholinguistic grain size theory. *Psychological Bulletin*, *131*(1), 3-29.

APPENDIX A: IRB Parental Consent Form

UNIVERSITY HEALTH SYSTEMS of Eastern Carolina

East Carolina University

Informed Consent to Participate in Research

Information to consider before taking part in research that has no more than minimal risk.

Title of Research Study: Effects of word length and word type on decoding and spelling abilities of fourth graders with and without reading impairments

Principal Investigator: Joanne Carfioli Naylor, M.S., CCC-SLP

Institution/Department or Division: Department of Communication Sciences and Disorders, College of Allied Health Sciences

Address: School of Allied Health Sciences, East Carolina University, Greenville, NC 27858-4353

Telephone #: Joanne Carfioli Naylor, (252) 744-6122 or Dr. Marianna Walker, (252) 737-3004

Researchers at East Carolina University (ECU) study problems in society, health problems, environmental problems, behavior problems and the human condition. Our goal is to try to find ways to improve the lives of you and others. To do this, we need the help of people who are willing to take part in research.

The person who is in charge of this research is called the Principal Investigator. The Principal Investigator may have other research staff members who will perform some of the procedures.

You may have questions that this form does not answer. If you do, feel free to ask the person explaining the study, as you go along. You may have questions later and you should ask those questions, as you think of them. There is no time limit for asking questions about this research.

You do not have to take part in this research. Take your time and think about the information that is provided. If you want, have a friend or family member go over this form with you before you decide. It is up to you. If you choose to be in the study, then you should sign the form when you are comfortable that you understand the information provided. If you do not want to take part in the study, you should not sign this form. That decision is yours and it is okay to decide not to volunteer.

Why is this research being done?

The purpose of this study is to investigate the impact of word type (real words, nonsense words), orthographic type (phonetic, nonphonetic), and word length (1-5 syllables) on the decoding (accuracy and rate) and spelling performance (accuracy, rate) of fourth graders with and without reading impairments using both standardized and experimental assessment tools. The goal is to learn if the use of both types of assessment tools provides an accurate picture of both reading and spelling abilities and can be used by Speech-Language Pathologists (SLP). The decision to allow your child to take part in this research is yours to make.

Why am I being invited to take part in this research?

Your child is being invited to take part in this research because your child is in the fourth grade and Joanne Carfioli Naylor, a Doctoral Candidate and the Principal Investigator (PI) is conducting research on reading and spelling abilities of fourth grade students. If you allow your child to volunteer to take part in this research, he/she will be one of seventy-five children to do so.

Are there reasons I should not take part in this research?

No, there are not any reasons your child should not take part in this research study.

What other choices do I have if I do not take part in this research?

You have the choice of your child not taking part in this research study.

Where is the research going to take place and how long will it last?

The research procedures will be conducted in the Reading Lab 2310Q in the Allied Health Sciences Building. Your child will be seen for two one-hour sessions during the research study for a maximum of two hours. The total amount of time your child will be asked to volunteer for this study is two hours.

What will I be asked to do?

You will be asked to do the following: You will need to answer some basic identifying questions about your child (including name, age, and birthday). Your child will be asked to take a series of standardized tests to measure nonverbal Intelligence Measure, receptive vocabulary reading of single words and grade level passages, and spelling in Session 1. Session 2 will include the completion of experimental tasks involving the reading of words presented on a computer screen, and two tasks involving the spelling of words. The examiner will be audio recording all of the answers provided by your child.

What possible harms or discomforts might I experience if I take part in the research?

There are always risks (the chance of harm) when taking part in research. It has been determined that the risks associated with this research are no more than what you would experience in a normal life.

However, some people react to things differently, so it is important for you to tell us as quickly as possible if you or your child experiences any negative feelings or problems.

Are there any reasons you might take me out of the research?

During the study, information about this research may become available that would be important to you. This includes information that, once learned, might cause you to change your mind about wanting to be in the study. We will tell you as soon as we can.

What are the possible benefits I may experience from taking part in this research?

This research might help us learn more about how well children in the fourth grade with and without reading disorders can decode words and nonsense words, spell them, and determine when they are spelled correctly and incorrectly. You will be provided with test scores relating to your child's pure tone hearing accuracy, receptive vocabulary, nonverbal intelligence, single word (real word and nonsense words) decoding abilities, and written spelling abilities from the pre-experimental testing if requested. There may be no personal benefit from your participation, but the information gained by doing this research may help others in the future.

Will I be paid for taking part in this research?

Your child will receive a $15.00 gift card if he/she completes both sessions of testing.

What will it cost me to take part in this research?

It will not cost you any money to be part of the research.

Who will know that I took part in this research and learn personal information about me?

To do this research, ECU and the people and organizations listed below may know that you took part in this research and may see information about you that is normally kept private. With your permission, these people may use your private information to do this research:

- The University & Medical Center Institutional Review Board (UMCIRB) and its staff, who have responsibility for overseeing your welfare during this research, and other ECU staff who oversee this research.

How will you keep the information you collect about me secure? How long will you keep it? All information collected during this research project will be kept in a locked filing cabinet in the Reading Lab, Allied Health Sciences Room 2310Q. The printed data will be kept with your information for seven years. Your information will have a special code, so that we know it belongs to your child. The information we collect may be used in future research using your special code, so that no one knows it was done by your child.

What if I decide I do not want to continue in this research?

If you decide you or your child no longer want to be in this research after it has already started, you may stop at any time. You will not be penalized or criticized for stopping.

Who should I contact if I have questions?

The people conducting this study will be available to answer any questions concerning this research, now or in the future. You may contact the Principal Investigator, Joanne Carfioli Naylor at (252) 744-6122 (Monday-Friday, between 9am-5pm).

If you have questions about your rights as someone taking part in research, you may call the UMCIRB Office at phone number (252) 744-2914 (days, 8:00 am-5:00 pm). If you would like to report a complaint or concern about this research study, you may call the Director of UMCIRB Office, at (252) 744-1971.

I have decided I want to take part in this research. What should I do now?

The person obtaining informed consent will ask you to read the following and if you agree, you should sign this form:

- I have read (or had read to me) all of the above information.
- I have had an opportunity to ask questions about things in this research I did not understand and have received satisfactory answers.
- I understand that I can stop taking part in this study at any time.
- By signing this informed consent form, I am not giving up any of my rights.
- I have been given a copy of this consent document, and it is mine to keep.

____

Participant's Name (PRINT)

____

Parent/Guardian Name (PRINT) Signature Date

Person Obtaining Informed Consent: I have conducted the initial informed consent process. I have orally reviewed the contents of the consent document with the person who has signed above, and answered all of the person’s questions about the research.

____

Person Obtaining Consent, Principal Investigator Signature Date

Appendix B: Child Case History Form

Child Case History by Parent Interview

1. **Child's Name: __________________ Birth date: _________**
2. **Gender (Male/Female): _____________**
3. **What is your child's native language: ____ English ____ Other: ____________**
4. **What best describes you/your child's race?**
   - ___ American Indian or Alaska Native
   - ___ Asian
   - ___ Black or African American
   - ___ Native Hawaiian or Other Pacific Islander
   - ___ White
   - ___ Other: __________________
5. **What is the highest level of education received by either parent?**
   (Please put "**M**" for Mother and "**F**" for Father)
   - ___Less than high school diploma
   - ___High school diploma/GED
   - ___ Some college
   - ___Associate's degree/2 year degree
   - ___4-year college degree
   - ___ Graduate/post-baccalaureate degree
6. **Do you suspect that your child has a speech and/or language problem?** Yes No
   If yes, please explain: ____
7. **Has your child ever received any speech and/or language services?** Yes No
   If yes, please explain: ____
8. **Has your child been diagnosed with any type of genetic syndrome (e.g., Autism, Down Syndrome)?** Yes No If yes, please explain:_______________________
9. **Has your child had any history of hearing problems, ear infections?** Yes No
   If yes, please explain: ____
10. **Does your child have attention difficulties or a diagnosis of Attention Deficit Disorder (ADD)/ Attention Deficit Hyperactivity Disorder (ADHD)?** Yes No
    If yes, please medication and dosage: ____________________________________
11. **Does your child have difficulty with reading?** Yes No
12. **Does your child have spelling difficulties?** Yes No
13. **Has your child repeated any grades?** Yes No If yes, which grade?____________
14. **Is there anything else we need to know about your child's learning and/or development?** If yes, please explain: _______________________________________
15. **How did you hear about this study?** _________________________

APPENDIX C: Real Word Stimulus Items

Real Words

Phonetic Words

1 syllable	care
	child
	dog
	lame*+
	step
2 syllable	address
	awake
	farmer
	himself
	hundred
3 syllable	example*
	family
	holiday
	nobody
	remember
4 syllable	accommodate*
	citizenship*
	evaluate*
	interesting*
	temperature*
5 syllable	elementary*
	extraordinary*
	nonrenewable*+
	parallelogram*+
	perpendicular*+

Nonphonetic Words

1 syllable	brought
	does
	height*
	knife
	should
2 syllable	airplane
	business*
	conscious*
	listen
	statue*
3 syllable	exercise*
	humorous*
	oxygen*
	restaurant*
	tragedy*
4 syllable	dictionary
	education*
	exaggerate*+
	usually
	vicinity*+
5 syllable	chronological*+
	electricity
	personality*
	pronunciation
	university

* low frequency per Bååth (2010)

+ low frequency per Davies (2010)

APPENDIX D: Spelling Decision Stimuli

Incorrect words

1 syllable:

duz (does)
cair (care)*
chid (child)*
nife (knife)
sep (step)*

---

2 syllable:

addres (address)*
airplan (airplane)
himsef (himself)*
hundrid (hundred)*
statu (statue)
lisen (listen)

---

3 syllable:

xample (example)
xercise (exercise)
rmember (remember)
trajedy (tragedy)

---

4 syllable:

visinity (vicinity)
electrisity (electricity)*
interestin (interesting)*
yuniversity (university)
accommodat (accommodate)*

---

5 syllable:

lementary (elementary)*
nonrenewabull (nonrenewable)*
pronunciashun (pronunciation)
sitizenship (citizenship)*
kronological (chronological)

* Phonetic

Table 14

Individual Data for Pre-Experimental Tests

ID	***Raven's Progressive Matrices*** **Percentile Rank**	***PPVT-4*** **Standard Score**	***WRMT-III*** **Word Id Standard Score**	***WRMT-III*** **Word Attack Standard Score**	***TWS-5*** **Standard Score**	**Reading Group**
1	95	133	114	115	105	Average
2	95	109	95	97	92	Average
3	75	94	105	106	100	Average
4	10	86	80	87	94	Reading Impairment
5	95	108	103	103	85	Average
6	95	119	106	77	98	Reading Impairment
7	10	111	64	69	83	Reading Impairment
8	95	145	129	119	141	Average
9	95	144	138	127	120	Average
10	80	119	84	68	83	Reading Impairment
11	95	116	111	115	102	Average
12	95	123	105	107	89	Average
13	95	132	141	143	130	Average
14	95	123	87	80	87	Reading Impairment
15	95	113	126	127	102	Average
16	50	98	99	100	104	Average
17	75	96	89	90	88	Average
18	60	123	100	97	97	Average
19	60	107	109	123	108	Average
20	10	79	86	101	103	Reading Impairment
21	95	88	96	101	95	Average
22	85	112	95	98	109	Average
23	95	98	123	119	111	Average
Mean	**76.09**	**112.00**	**103.70**	**103.00**	**101.13**	
Std Dev.	**29.43**	**17.58**	**18.90**	**19.19**	**14.54**	