THE EFFECT OF COLOR CODING EXTERIOR LETTERS OF WORDS ON READING FLUENCY AND DECODING ABILITY IN INTERMEDIATE STUDENTS WHO READ BELOW GRADE LEVEL

by

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Liberty University

A Dissertation Presented in Partial Fulfillment

Of the Requirements for the Degree

Doctor of Education

Liberty University

2018

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ABSTRACT

The purpose of this true experimental, posttest-only control-group design was to determine if the color coding of exterior letters affects the fluency and decoding ability among fourth grade students who were below grade level in reading. If color coding exterior letters is an effective intervention, then struggling readers could utilize this intervention to improve their reading fluency and decoding abilities. Participants were selected from a random sample of 102 public school students who were below grade level in reading. The participants were from a district in the southeast United States. Each student was randomly assigned to either an experimental or control group. Both groups received identical tests from the Houghton Mifflin (2009) diagnostic assessment in real word decoding, pseudoword decoding, and fluency, except that the exterior letters of words were colored blue for the treatment group, while all letters were black for the control group. The real word decoding assessment revealed no statistically significant difference between the mean scores of the control group and treatment group. There was a statistically significant difference between the mean scores of the control group and treatment group for the pseudoword decoding assessment and fluency assessment. While current research indicates that the exterior letters of a word play an essential role when reading, based on a review of the literature, including searches from ERIC (Ebsco), ETS Online Research Library, Education Research Complete, Children's Literature Comprehensive Database, and ProQuest Education Journals, there are currently no color interventions that assist readers in focusing on exterior letters. Future research should focus on conducting follow up studies on the effectiveness of this intervention and test the effectiveness of color coding other morphological elements of words.

Keywords: Color coding exterior letters, exterior letter interventions, reading intervention exterior letter.

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List of Abbreviations

Consortium on Reading Excellence Phonics Survey (CORE-PS)

Curriculum-Based Measurement (CBM)

Tennessee Comprehensive Assessment Program (TCAP)

Consonant Vowel Consonant (CVC)

CHAPTER ONE: INTRODUCTION

Overview

The following chapter contains a synopsis of the relevant information concerning the parts of a word a reader focuses on when reading and what colors are most likely to gain the attention of the human eye. Ultimately, the study took the combination of these two phenomena and determined if an effective literacy intervention for struggling readers can be developed. Chapter One provides an overview of the study including the background, problem and purpose statements, significance, research questions and hypotheses, identification of variables, definitions, assumptions and limitations, as well as the research summary.

Background

Something as simple as adding color during reading can ease the distress that students with reading delays experience when they encounter a text (Harries, Hall, Ray, & Stein, 2015). Coloring the first and last letter of a word could make a struggling reader a more fluent reader. Scientific studies on how the brain processes information when reading indicates that the exterior letters of a word have a privileged role compared to the interior letters (Paterson, Read, McGowan, & Jordan, 2014). Johnson and Eisler (2012) conducted an experiment in which participants read sentences containing words with transposed letters occurring at the beginning of the word, near the middle of the word, and at the end of the word. Johnson and Eisler (2012) concluded that the first letter of a word has a privileged role over interior letters and that the last letter of a word is also more important than the interior letters. The last three decades have contained numerous findings that indicate the privileged role of exterior letters within a word (Paterson et al., 2014).

Harries et al. (2015) studied the significance of colors and reading delay and concluded that colors alleviate visual stress and have the potential to impact future reading interventions. Hall, Ray, Harries, and Stein (2013) compared colored filter systems in children with reading disabilities and concluded that children with reading disabilities, like dyslexia, often struggle with visual stress. The results indicate that color reduces visual stress and note that further vigorous research into the effects of color and reading will need to be done (Hall et al., 2013).

Despite the findings that indicate the privileged role of exterior letters and the positive effects color has on visual processing, there does not seem to be any prominent educational strategies that prompt students to focus on the exterior letter as a reading intervention. This study introduced an intervention that color coded the exterior letters of a word as a reading intervention for fourth-grade students who were below grade level in reading.

In reviewing the literature, it was found that the theoretical framework for color coding exterior letters as a reading intervention, which was used in this study, is based on the theories of information processing as developed by Miller (1956). The basic idea of information processing is that theories can be developed that describe the way in which information, pertaining to mental stimulation and responses, is represented and processed by humans (Proctor & Vu, 2006). As applied to this study, the independent variable, the presence of color coded exterior letters, explained the dependent variables, reading fluency, decoding real words, and decoding pseudowords, because word recognition is influenced profoundly by a perceptual unit formed from two letters of maximum separation in words (Paterson et al., 2014), and causing these letters to stand out might prompt the brain to decode words more effectively.

Problem Statement

For several decades there has been ongoing research analyzing the portions of a word that play a privileged role when reading and studies that analyze the role colors play when reading. Experimental psychological findings indicate that word recognition is influenced profoundly by a perceptual unit formed from two letters of maximum separation in words; namely, the first and the last letters (Jordan, Thomas, & Patching, 2013). Kohnen, Nickels, Castles, Friedmann, & McArthur (2012) note that position coding for exterior letters is less ambiguous, possibly because exterior letters have a perceptual advantage, being adjacent to a space and with fewer neighboring letters introducing noise to the position coding. Exterior letters may also act as processing anchors and may be given more processing resources (Kohnen et al., 2012). Shetreet and Friedmann (2011) also found that the first and final letters are often perceived and identified correctly more often than other (middle) letters. Iovino, Fletcher, Breitmeyer, and Foorman (1998) researched the effects of colored overlays in children with reading disabilities and concluded that color did increase reading fluency in some children. They also recommended that future research be applied to color and reading that included rigorous selection criteria and suitable statistical analysis to determine which children would benefit from color changes in reading.

Johnson and Eisler (2012) studied the importance of the first and last letters in words during reading and concluded that these letters play a preferential role. Johnson and Eisler (2012) note that these findings should influence current and future reading theory and further research should be done to determine why letter position effects reading. Johnson and Eisler (2012) also call future research to investigate which reading strategies, that utilize exterior letter interventions, are most effective. Harries et al. (2015) studied the significance of colors and

reading delay and concluded that colors alleviate visual stress and have the potential to impact future reading interventions. Hall et al. (2013) compared colored filter systems in children with reading disabilities and concluded that children with reading disabilities like dyslexia often struggle with visual stress. The study by Hall et al. (2013) results indicate that color reduces visual stress and notes that further vigorous research, into the effects of color and reading, will need to be done. This study hoped to couple the call to further research into the importance of both exterior letters and color into an effective reading strategy for struggling readers. The problem is that while current research has well established that both the exterior letters of a word and color coding play an essential role when reading, there are currently no reading interventions that attempt to anchor one's visual fixations on the exterior letters by color coding them as a decoding and fluency intervention for struggling readers.

Purpose Statement

Due to the lack of reading interventions that attempt to anchor one's visual fixations on the exterior letters of a word, the purpose of this true experimental post-test only control-group study was to compare color coding exterior letters to reading fluency, decoding real words, and decoding pseudowords for intermediate students below grade level in reading in a southeastern United States school district. The independent variable was the presence of color coded exterior letters in a leveled high frequency word list. It is generally defined as applying a different color to the first and last letter of words on a leveled word list and applying a different color to the first and last letter of words in a reading passage. The dependent variable was the ability of intermediate students, who were below grade level in reading, to decode a high frequency word list with real words and pseudowords and fluently read a leveled reading passage.

Significance of Study

Since the ability to read is a fundamental task that most academic subjects build upon, those who are unable to fluently read are at an educational disadvantage in many areas of study. Insufficient basic educational concepts, including the ability to read, are considered a significant risk factor for a self-determined life and for participating in employment (Thielen, 2013). Inadequate reading skills have highly different impacts on employment and career paths (Thielen, 2013). Interventions to assist struggling readers should therefore be paramount to improving their fluency and comprehension.

The use of reading interventions that are based on how the brain processes words when reading and how the eye focuses on particular letters might result in significant academic growth in reading. Johnson and Eisler (2012) found that both the first and last letters of a word have a privileged role over interior letters of words. Johnson and Eisler (2012) suggest that exterior letters are important because they are related to how the mind either organizes lexical information or retrieves that lexical information. Shetreet and Friedmann (2011) note that the first and last letters in the word are more easily identified for readers with letter position dyslexia. Scaltritti and Balota (2013) mention that the exterior letters of a word are more salient.

This study expected to prompt the mind into accessing lexical information by highlighting the most important part of the word, the exterior letters. Color coding the exterior letters could make it easier for the brain to extract information from the visual stimuli and aid students in the reading processes. This research was seeking to address a primary gap in literature, the absence of a reading intervention that color codes the exterior letters of a word. Policymakers could use the results of this study to implement future reading interventions for struggling readers.

Cummings, Dewey, Latimer, and Good (2011) investigated the effects of pseudowords on phonemic decoding skills. Pseudowords are designed to determine a student's understanding of grapheme-phoneme relations and phonemic awareness and do not allow for students to rely on sight word knowledge in reading (Cummings et al., 2011). Cummings et al. (2011) found that the ability to decode pseudowords was correlated with reading fluency and reading outcomes in both directions. This indicates that poor decoding skills of pseudowords was associated with poor reading fluency while good decoding skills of pseudowords was associated with improved reading fluency (Cummings et al., 2011). Therefore, a proper assessment for the effectiveness of a reading intervention, that utilizes the use of color coding exterior letters of words, should evaluate the reader's ability to decode pseudowords along with real words.

Research Questions

RQ1: Is there a difference in the ability to decode real words between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level?

RQ2: Is there a difference in the ability to decode pseudowords between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level?

RQ3: Is there a difference in the reading fluency of a reading passage between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level?

Definitions

1. *Anagram Pairs* - When letter identities are equated across particular letter pairs (e.g., in the anagram pair *case* and *aces* the letter pairs *a* and *s*, and *c* and *e* each occur twice) (Jordan, Thomas, Patching, Scott-Brown, 2003).
2. *Anagrammatical Error* - When a word is misread because the letters of the word were intentionally rearranged by the writer (Paterson et al., 2014).
3. *Color coding* - A system of displaying information using different colors (Wichmann, Sharpe, & Gegenfurtner, 2002).
4. *End Neighbors* - Orthographic neighborhoods sharing the same final letters (Lavidor, Hayes, Shillcock, & Ellis, 2004).
5. *Exterior Letters* - Two letters of maximum separation in words; The first and last letter of words (Jordan, Thomas, & Patching, 2003).
6. *Fovea* - The part of the eye that focuses on specific details such as reading (Just & Carpenter, 1980).
7. *Lead Neighbors* - When the initial letters for an orthographic neighbor are the same (Lavidor et al., 2004).
8. *Migration Error* - When a reader mistakes a word for its anagram pair (i.e. reading the word cloud as “could”) (Kohnen & Castles, 2013).
9. *Orthographic Neighbors* - Same length words differing from a target word by one letter (i.e. the word marsh has two neighbors: harsh and march) (Lavidor et al., 2004).
10. *Parafovea* - Details that the eye focuses on that are peripheral to what the fovea is focusing on (Schotter, Angele, & Rayner, 2012).

11. *Priming* - A memory effect in which exposure to one stimulus influences a response to another stimulus (Perea & Carreiras, 2006).
12. *Pseudoword* - A string of letters that appears similar to a real word in relation to its orthographic and phonological arrangement but does not occur in the language (Cummings et al., 2011).
13. *Reading fluency* - The rate at which someone is able to read a text (Harm & Seidenberg, 2004).
14. *Substituted Letters* - When a letter from a word is substituted with another letter making the original word a non-word (ex. stop and szop) (Johnson, Perea, & Rayner, 2007).
15. *Transposed Letters* - When two letters in a word's position are reversed (ex. stop and sotp) (Johnson et al., 2007).
16. *Word Attack Skills* -The ability to distinguish patterns, blend together multiple sounds to form words, segment words into isolated sounds, and transfer these skills to the reading of words in connected text (Nelson, Alexander, Williams, & Sudweeks, 2014).
17. *Word decoding* -The ability to apply one's knowledge of letter patterns and letter-sound relationships to correctly pronounce written words (Harm & Seidenberg, 2004).
18. *Orthographic Processing*- Using one's visual systems to retain the way a word looks for the purpose of forming, storing, and recalling words (Aaron et al., 1999).

CHAPTER TWO: LITERATURE REVIEW

Overview

Chapter Two reviews the literature available to provide history and background on the information processing theory as well as explore how the information processing theory applies to reading. This chapter addresses how visual stimuli and color affect reading, explore the split-fovea model, and delve into the importance of exterior letters in word recognition. Chapter Two hopes to provide the necessary reasoning for why color coding exterior letters of words is a valuable area of research.

Theoretical Framework

The information process theory identifies the flow of information through the cognitive system (Miller, 2011). According to this theory, humans do not simply respond to mental stimuli, rather content from the environment is analyzed through mental processes (Miller, 2011). Information processing theorists attempt to quantify how well brain signals encode information and how well these systems, by acting on signals, process information (Sinanović & Johnson, 2007). The information processing approach addresses complex thinking (Miller, 2011). Information processing tries to specify a variety of cognitive processes, ranging from the simple detection of a stimulus to the development of complex rules, strategies, and concepts (Miller, 2011). Furthermore, the information process theory attempts to characterize how perception, attention, memory, language, and abstract mental operations are interrelated (Miller, 2011).

The Information processing theory did not largely come into play until the mid-20th century. Despite how efficient humans are at critical thinking, it was not until the 1950s that researchers developed systematic models of memory, cognition, and thinking (Schraw &

McCrudden, 2009). Many of the leaps and bounds in the information processing theory resulted from comparisons and experiments relating to military technology. In fact, information processing was the first major theory of adult cognition to arise since developmental psychology had become an experimental science (Miller, 2011). Miller (2011) credits World War II and the Korean War to the advances made in information processing because these events caused psychologists to begin to think of humans as information transmitters and decision makers when they examined how military personnel divided their attention between a plane's controls and instructions from a radio, detected blips on a radar screen, and interpreted a plane's instrument readings. Furthermore, advances in communication engineering influenced information theory (Miller, 2011). Miller (2011) notes that engineers working on communication systems, such as the telephone, telegraph, radio, and early computers, developed the notion of "communication channels," which came to serve as a metaphor for human thought. Since these advances started in the 1950s, neuroscientists have used information processing theory to hypothesize how nerve cells function (Dimitrov, Lazar, & Victor, 2011).

Scientists now analogize that the mode in which humans face problem solving situations on the information processing theory is that of a computer program (Simon, 1962). Schraw and McCrudden (2009), agree that people process information with remarkable efficiency and often have better performance than highly sophisticated machines. The pathways in which information is retained and regurgitated are comprised of an organized system of processes and of organizations of memory contents (Simon, 1962). According to Miller (2011), this flow begins with an input and ends with an output. Input information can be a mathematical problem that needs to be solved, a written passage, or even an event that is taken into the human information processing system (Miller, 2011). The output is where the flow of information ends

and can be a decision, motor behavior, speech, or even information stored in long-term memory (Miller, 2011). In some neurological circles, information processing theory is known as "Neural Information Flow," for identifying how much information moves through the nervous system, and the constraints that information theory imposes on the capabilities of neural systems for communication, computation, and behavior (Dimitrov et al., 2011).

Information Processing, Sensory Memory, and Color

The information processing approach addresses complex thinking (Miller, 2011). Information processing tries to specify a variety of cognitive processes, ranging from the simple detection of a stimulus to the development of complex rules, strategies, and concepts (Miller, 2011). Furthermore, the information process theory attempts to characterize how perception, attention, memory, language, and abstract mental operations are interrelated (Miller, 2011).

A subset of information processing theory is sensory memory. This subset specifically studies how external factors and visual stimuli affect one's memory functioning (Schraw & McCrudden, 2009). According to Schraw and McCrudden (2009), the main purpose of sensory memory is to screen incoming stimuli and process only those stimuli that are most relevant at the present time. Wichmann et al. (2002) note that color is an important aspect of sensory memory. Color plays a highly specialized role in certain image segmentation tasks (Wichmann et al., 2002). Wichmann et al. (2002) also note that color coding appears as if it might be important for the rapid identification and recognition of objects. Ostergaard and Davidoff (1985) found a significant effect of color on object naming latencies using color versus black-and-white photographs on objects.

Information processing has also attempted to discover the neural pathways affected by reading in hopes to target specific brain functions in struggling readers. According to

Christodoulou et al. (2014), impaired reading fluency could arise from several different sources. Historically, it has been associated with impaired phonological awareness that occurs even before the onset of reading instruction (Christodoulou et al., 2014). Dysfunctional reading has also been associated with impaired naming speed for lists of stimuli (Christodoulou et al., 2014). Additionally, impaired reading fluency can also be attributed to temporal processing impairments within the brain (Christodoulou et al., 2014). The study by Christodoulou et al. (2014) sought to determine the effects of reading fluency on brain neurons. Christodoulou et al. (2014) identified brain regions and how their activation changed in response to word presentation using functional magnetic resonance imaging (fMRI). The fMRI method is a non-invasive measure to view signal activity within the brain (Christodoulou et al., 2014). When neurons respond within the brain the blood oxygenation levels change causing a signal, like a flare, to be emitted. Based on where the signals are emitted within the brain researchers can pinpoint which areas of brain tissue are activated during different types of activities (Christodoulou et al., 2014).

In the study by Christodoulou et al. (2014), participants were asked to read a sentence containing five words presented in order and then respond either that the sentence was semantically plausible or non-plausible (e.g., *Bulls charge with great ferocity* vs. *Kangaroos type for their jobs*). The words were presented at either slow, medium, or fast speeds. The slow speed correlated with readers' grade level three or four, medium with eight or nine, and fast was correlated with greater than college level reading (Christodoulou et al., 2014).

The imaging was completed using a Siemens 3T Magnetic Resonance Imaging, a Tim System, and a 12-Channel Matrix head coil. After being calibrated to each patient, high resolution structural whole brain images where obtained during the sentence reading portion of the trial.

When the participants responded to sentence plausibility, accuracy and reaction times were recorded.

The study conducted by Christodoulou et al. (2014) largely found that in typical readers, the left hemisphere of the brain plays a greater role in reading than the right hemisphere. Using fMRI, word processing was found to be associated with greater activation on the left temporal lobe and left inferior frontal gyrus (Christodoulou et al., 2014). The left occipito-temporal cortex is activated when reading and processing accelerated text (Christodoulou et al., 2014). Higher scores in reading tests have been associated with increased activation in the left temporo-parietal and ventral occipito-temporal regions (Christodoulou et al., 2014). Among readers with dyslexia or reading dysfunction, hypo-activation was found in the left occipito-temporal gyrus and bilaterally in the parietal cortices (Christodoulou et al., 2014). The left hemisphere of the brain showed significantly less activation among those with reading dysfunction as compared with control groups (Christodoulou et al., 2014).

The left superior temporal gyrus is involved with semantic judgment and was activated more in readers without dysfunction to a degree that was statistically significant ($p = .01$) (Christodoulou et al., 2014). The left inferior frontal gyrus was also activated more in readers without dysfunction ($p = .02$), and is important in extracting meaning from words and semantic processing of sentences (Christodoulou et al., 2014). By targeting different portions of the brain it may be possible to tailor reading interventions to students with reading dysfunction (Christodoulou et al., 2014).

Visual processing impairments have been found to affect reading skills in many disabled readers (Barron, 1996). As an intervention for students with disabilities in reading who have visual impairments, Fiedler (1992) proposes that the use of colored lenses in glasses has assisted

individuals with Scotopic Sensitivity Syndrome in increasing their reading ability. Fiedler (1992) credits the success of this intervention to the fact that spectral light can be changed with the use of colored filters and this causes stability of the print, which in turn causes an increase in reading fluency and comprehension.

Iovino et al. (1998) assert that many children with reading disabilities have decreased transient channel processing rates, and therefore, ineffective transient-on-sustained channel inhibition. Consequently, Iovino et al. (1998) states that normal saccadic suppression (an outcome of this inter-channel inhibition) is altered, causing retinal images to persist past the physical duration of the stimuli (visual persistence). The result is superimposition of successive inputs, so that the letters in words appear superimposed and jumbled when reading across a page (Iovino et al., 1998). A series of visual persistence studies by Lovegrove, Garzia, and Nicholson (1990) concurs with the analysis of Iovino et al. (1998) by finding that more than 75% of children with reading disabilities were reported to have a visual deficit.

These findings have led researchers to develop interventions that attempt to modify visual transient channel processing. In a study by Iovino et al. (1998) where colored overlays were placed over reading passages in an attempt to improve visual defects in students with reading disabilities it was revealed that blue overlays significantly improved reading comprehension accuracy relative to reading without an overlay, $F(1, 56) = 4.72$, $p = .03$. The percentage of children who showed improved performance with a blue transparency was 57%. Iovino et al. (1998) also noted that using a red-colored transparency did not significantly affect reading comprehension accuracy, $F(1, 56) = 0.02$, $p = .88$. Only twenty-nine of the 60 children (48%) showed improved accuracy with the red overlay and 27 of the 60 children (45%) declined in accuracy from baseline. Iovino et al. (1998) conclude that blue overlays significantly increase reading comprehension performance and

reduces the rate of reading passages regardless of whether the individual is classified as reading disabled or has attention deficit disorder.

The decrease in accuracy when students were exposed to red overlays may have something to do with the color red and impaired psychological functioning. Elliot, Maier, Moller, Friedman, and Meinhardt (2007) hypothesized that the color red will impair performance on achievement tasks because red is associated with danger of failure in achievement contexts and evokes avoidance motivations. This might be accounted for by the repeated pairing of red with mistakes and failures that is encountered by most children in the education system (e.g., incorrect answers marked with red ink). This teaches students to associate red with failure in achievement contexts (Elliot et al., 2007). In an analogy test given to participants where the paper was either red, green, or white with black letters, students were assessed and results indicated that participants in the red condition performed worse than those in the green condition, $t(28) = 3.78$, $p<.01$, and the white condition, $t(29) = 3.26$, $p<.01$. Participants in the green and white conditions displayed comparable levels of performance, $t = -0.62$, $p> .53$ (Elliot et al., 2007).

Information Processing and Split Fovea Theory

According to the split fovea theory, visual word recognition of centrally presented words is mediated by the splitting of the foveal image, with letters to the left of fixation being projected to the right hemisphere and letters to the right of fixation being projected to the left hemisphere (Lavidor et al., 2004). This means when a reader focuses on a word, the fovea of the eye is fixated on the center of the word. The letters to the left of the center are projected to the right hemisphere of the brain, and the letters to the right of the word are projected to the left hemisphere of the brain.

Lavidor et al. (2004) notes that in the split fovea model the right hemisphere is assumed to reflect orthographical neighbor effects invoked by the initial letters of English words, and the left hemisphere orthographical neighbors of the end letters. For example, the right hemisphere would be invoked with the letters "M" and "A" in the word MARCH, while the left hemisphere would be invoked with the letters "C" and "H". The major assumption tested in the study conducted by Lavidor et al. (2004) is that in lexical decision making, the initial and final letters in word recognition play a superior role under the split fovea model. Lavidor et al. (2004) also notes that words are not always simple and symmetrical. Furthermore, initial letter sequences may be more informative than end letters (Lavidor et al., 2004). An example of an informative initial letter sequences would be filling in the missing letters in MARC_ vs. _ARCH. Lavidor et al. (2004) suggests it is much easier for the human mind to conclude MARCH from MARC_ than to come up with MARCH from _ARCH.

Lavidor et al. (2004) conducted an experiment that assessed the significance of orthographic lead neighbors and orthographic end neighbors in word recognition. The experiment was divided into two parts. The first portion of the test assessed the importance of orthographic lead neighbors and the second portion measured the importance of orthographic end neighbors. In both portions students had to promptly respond to and accurately identify a cluster of letters as either words or non-words. The first experiment utilized twenty-five graduate or post graduate students. Eighty words and eighty non-words that each contained six letters were used as the stimuli. The words or non-words were made of either the same lead neighbors or the same end neighbors. Neighbors were defined as three letter groups. The words or non-words were presented to the testees on a computer monitor and the testee had to respond via a button for either word or non-word. Orthographic neighborhood was found to have a significant effect on

response latency ($p < .01$). The second experiment was designed in the same fashion, however, the words or non-words were shown on the computer either positioned to the left or the right side of visual fixation. The visual field in which the target word was represented was found to have a significant effect on response latency. Words intended to stimulate the right visual field were perceived faster. Lavidor et al. (2004) concluded that testees responded faster and more accurately to the orthographic lead neighbor portion of the assessment than they did to orthographic end neighbors portion. The orthographic lead neighborhood portion had a significant effect on response latency $F(3,72) = 5.91$, $p < .01$ (Lavidor et al., 2004).

Related Literature

Reading Interventions and Decoding Strategies

Torgesen et al. (2001) note that when children who are below grade level in reading encounter a word they are not familiar with, they tend to place too much reliance on guessing the word based on the context of the passage. Many students with reading disabilities, according to Torgesen et al. (2001), have a severely impaired ability to use phonics to assist in the word identification process. Word reading difficulties of children with reading disabilities are caused primarily by weakness in their ability to process the phonological features of language (Torgesen et al., 2001). Torgesen et al. (2001) notes that current theories about the growth of word reading ability suggest that phonemic decoding skills play a critical supporting role as children begin to acquire the orthographic reading skills that enable relatively fluent and effortless identification of words in texts. Interventions to alleviate reading disabilities should therefore focus on providing students with tools to enhance their phonemic decoding skills.

Pritchard, Coltheart, Marinus, and Castles (2016) stress the importance of decoding words. Basic decoding skills require phonological awareness which is the ability to translate

letters or letter patterns into sounds (Pritchard et al., 2016). Wolf (2016) further notes that the failure to adequately develop reading decoding skills is an indicator of life long reading illiteracy. Wolf (2016) argues that in order to have adequate reading comprehension, the decoding process must be an involuntary habit that occurs without effort. Primary failures in decoding skills stem from failures in phonological awareness (Wolf, 2016). Pritchard et al. (2016) also investigated the significance of pseudowords and phonological decoding skills. Pritchard et al. (2016) assert that deficits in decoding can be linked to dyslexia and other reading disorders. Garcia and Cain (2013) performed a meta-analysis of 110 studies and concluded that regardless of the test used to determine reading comprehension, decoding skills had either a moderate or high correlation with performance on the test.

Significance of Pseudowords in Reading

Cummings et al. (2011) investigated the effects of pseudowords on phonemic decoding skills. Pseudowords are designed to determine a student's understanding of grapheme-phoneme relations and phonemic awareness and do not allow for students to rely on sight word knowledge in reading (Cummings et al., 2011). Cummings et al. (2011) found that the ability to decode pseudowords was correlated with reading fluency and reading outcomes in both directions. This indicates that poor decoding skills of pseudowords was associated with poor reading fluency while good decoding skills of pseudowords was associated with improved reading fluency (Cummings et al., 2011).

England and Gibson (2015) assert that one of the most accurate measures of phonological processing skill is the ability to read pseudowords. Pseudowords are combinations of letters that are not real words but can be read by following grapheme-phoneme conversion rules (England & Gibson, 2015). A child's ability to decode pseudowords is a strong indicator that the child has

sufficient skills to understand alphabetical mapping (England & Gibson, 2015). England and Gibson (2015) also assert that in both children and adults the rate of reading pseudowords is associated with increased reading skill. England and Gibson (2015) mention that pseudoword fluency is a strong predictor of reading difficulty. According to England and Gibson (2015), pseudowords are essential in testing reading decoding and fluency because pseudowords control for random word recognition.

Target Word Priming in Visual Word Recognition

Grainger and Whitney (2004) argue that word recognition is facilitated when priming precedes a target word and is composed of a subset of a target word's letters, as long as the shared letters are in the same order in prime and target stimuli. Priming, according to Grainger and Whitney (2004), occurs only when relative positions are respected. An example Grainger and Whitney (2004) offer is the six letter word "garden." It is identified more rapidly when preceded by the masked prime "grdn" compared to the unrelated condition "pmts," and changing the order of the exterior letters "nrdg" destroys the priming effect.

Transposed-Letter Effects in Reading

Johnson et al. (2007) mention the importance of letter position in identifying and decoding written words. If letter identity and position did not play a role in written word identification, then readers would be unable to distinguish between anagrams such as stop, pots, tops, opts, post, and spot (Johnson et al., 2007). Furthermore, Johnson et al. (2007) note that when letters of a word are transposed they are much more similar to the base word than when letters of a word are substituted. For example, Johnson et al. (2007) note that the transposed letter non-word *jugde* is intuitively more similar to the base word *judge* than the substituted letter

non-word *judre*. Johnson et al. (2007) assert that transposed letter non-words can significantly activate the lexical representation of their base word.

Johnson et al. (2007) also assert that readers acquire certain types of information from the parafovea. For example, many readers can process a word adjacent to the word they are fixating on before their eyes actually focus on the adjacent word (Johnson et al., 2007). Readers often skip words, thus indicating that it is possible for an entire word located in the parafovea to be processed while fixating on an adjacent word (Johnson et al., 2007). Johnson et al. (2007) maintains that in order for readers to obtain information from words located in the parafovea, readers must obtain phonological codes as well as abstract letter codes from the parafovea based on visual features and orthographic rules. Important features of a word that facilitates in obtaining orthographic information from a parafoveal word may include information such as the first set of letters of the parafoveal word, the final letters of a parafoveal word, the exterior letters of a parafoveal word, or the order of internal letters of a parafoveal word.

Johnson et al. (2007) based their research on these conclusions and conducted an experiment that sought to determine the effects transposed and substituted letters have on word recognition. Johnson et al. (2007) hypothesize that if the parafovea does not extract information about letter identity then there will be no such thing as transposed effects. The experiment performed by Johnson et al. (2007) involved five manipulations to target words. The first manipulation in which the target word was the same is called *identity*. Johnson et al. (2007) conducted a second manipulation which involved the transposition of two internal and adjacent letters such as *jugde* for *judge.* The third manipulation involved substituting two internal and adjacent letters such as *junpe* for *judge*. The fourth manipulation performed by Johnson et al. (2007) involved transposing the two final letters such as *judeg* for *judge* and the fifth

manipulation involved substituting the two final letters such as *judnp* for *judge*. The subjects sat in front of a computer screen that projected sentences with the target words in them. A separate machine measured eye movements. The amount of time the eye spent fixating on the target word is reflective of processing time for that word (Johnson et al., 2007).

The four nonidentity conditions were analyzed by Johnson et al. (2007) using a 2 x 2 ANOVA comparing type of manipulation (transposition or substitution) by letter manipulation position (internal or final). Johnson et al. (2007) found that a preview involving a transposition of two letters resulted in shorter viewing durations than previews involving a substitution of two letters ($p < .05$). Letter manipulation position was not found to be significant (Johnson et al., 2007). Johnson et al. (2007) did determine that final letter identity is significant. When comparing identity letters versus substituted letters for the final two letters, viewing duration was shorter for the identity word across the board ($p < .001$) (Johnson et al., 2007). This finding indicates the final two letters are significant in word comprehension.

Exterior Letter Prevalence in Visual Word Recognition

Shillcock and Monghan (2003) mention the fact that there is considerable evidence that first and last letters of an isolated word receive preferential processing. A split-fovea model, according to Shillcock and Monghan (2003), automatically prioritizes the processing of these exterior letters. In fact, if the identity of the letters in the two hemi-fields of a centrally fixated word is known, then specifying the first and last letter of the word necessarily identifies all the four-letter words, and only leaves a fraction of one percent of the lexicon ambiguous (Shillcock & Monghan, 2003).

Jordan, Thomas, and Patching (2003) propose that word recognition is mediated by perception of familiar, sub word letter groups and that these letter groups provide perceptual

units through which lexical access is ultimately attained. An example mentioned by Jordan, Thomas, and Patching (2003) is the word "clock" and how this word may be recognized through the use of stored representations for the letter groups *cl* and *ock*. Jordan, Thomas, and Patching (2003) conclude that in a system of this kind, recognition of words in which familiar letter groups are naturally present would be relatively rapid because word recognition can benefit from processing these familiar features. In contrast, Jordan, Thomas, and Patching (2003) argue that stimuli that do not contain these features, e.g., illegal nonwords, like *dkpj*, which do not contain familiar letter groups, cannot benefit from this enhanced processing, and so performance with this stimuli suffers.

Jordan, Thomas, and Patching (2003) inquire which letter groups contribute to word recognition, and which groups contribute the most. This concept is known as word priming. The goal is to present some of the same letters from a target word in the correct position in either another word or non-word prior to visualization of the target word in hopes that the priming will help readers with word recognition (Jordan, Thomas, &Patching, 2003). Historically, many researchers conclude that the exterior letters of a word contribute the most to word recognition. For example, Forster and Gartlan (1975) reported a lexical decision experiment in which the presentation of a word was preceded immediately by a display of its first two and its last two letters, its middle letters, its last four letters, or its first four letters. Only when the exterior letters were preceded by the target word did word priming occur (Forster & Gartlan, 1975). Forster and Gartlan (1975) propose that letters from the extremities of words are normally the first to be perceived and are combined to form units that are significant contributors to word recognition.

McCusker, Gough, & Bias (1981) concurred with the findings of Forster and Gartlan (1975) but also suggested that these priming effects were reported due to the perception of only

the exterior letter pairs rather than the first two and last two letters. In the study produced by McCusker et al. (1981), four letter words were primed by briefly presenting both exterior letters or both interior letters immediately before the whole word was shown. McCusker et al. (1981) concluded that words were named more quickly when exterior letter pairs preceded each target word display.

Humphreys, Evett, and Quinlan (1990) conducted an experiment that explored the effects of word priming and the differences made by letter location. Humphreys et al. (1990) utilized what is called a four-field masking technique in which words were presented in the following sequence: mask, prime, target, mask. For example, the word *date*: *#### doce date ####*. The degree and position of letter primes was manipulated throughout the study to determine which types of primes were most effective in causing target word comprehension. Humphreys et al. (1990) found that perception of target words (e.g. *found*) was simplified when primes and targets shared both exterior letters (*femrd*) compared with when primes shared interior letters (*gound*), the first two letters (*fomeb*), last two letters (*grend*), or no letters at all (*besut*) ($p < .01$). Target word identification improved when the target word and the prime shared the exterior letters. No priming was found when the target word and the prime shared the same letters, but not the same letter positions. Humphreys et al. (1990) concluded that the evidence from priming indicates that the exterior letter pairs of words play a particularly important role in word recognition. Humphreys et al. (1990) postulate that exterior letters serve as an anchor-point for coding the positions of other letters within a word.

Jordan, Thomas, and Patching (2003) also note that exterior letter pairs play a major role in single word recognition. In a study that was examined by visually degrading letter pairs in three positions in words (initial, exterior, and interior), each degradation slowed reading rate

compared with an undegraded control (Jordan, Thomas, & Patching, 2003). Jordan, Thomas, and Patching (2003) found that while degrading initial and interior pairs slowed the reading rate to a similar extent, degrading exterior pairs slowed reading rate most of all. Moreover, Jordan, Thomas, and Patching (2003) point out that these effects were obtained when letter identities across pair positions varied naturally and when they were matched.

Jordan, Thomas, and Patching (2003) divided their research into two experiments. In the first, Jordan, Thomas, and Patching (2003) used a group of 16 students who read a text selection of 540 words. Approximately one in ten words in the passage was degraded so that either initial, exterior, or interior letter pairs were blurred and more difficult to read as compared with other letters (Jordan, Thomas, & Patching, 2003). Some passages in the study Jordan, Thomas, and Patching (2003) had no words degraded as controls. Each participant had only one of the options degraded or none degraded (Jordan, Thomas, & Patching, 2003). The participants read the passages, hit a stop timer at the end, then had to answer questions for comprehension (Jordan, Thomas, & Patching, 2003).

The results were analyzed based on reading rate and passing the comprehension questions (Jordan, Thomas, & Patching, 2003). ANOVA was used to analyze the results. Newman-Keul's post hoc comparisons demonstrated that participants in the no degradation condition read faster than in any other group ($p < .01$) (Jordan, Thomas, & Patching, 2003). This finding demonstrates that degrading letters is detrimental to reading time (Jordan, Thomas, & Patching, 2003). Reading times for initial and interior degradation did not differ ($p = .74$); however, when both exterior letters were degraded reading rate was found to be significantly slower ($p < .01$) (Jordan, Thomas, & Patching, 2003). Reading comprehension did not vary across the four groups ($F < 1$) and had a mean accuracy of 83% (range = 60%-100%) Jordan, Thomas, & Patching, 2003).

These results indicate that the role of exterior letters in single-word recognition is of greater significance than interior letter pairs. Being able to correctly identify exterior letters should increase ready accuracy.

In the second experiment Jordan, Thomas, and Patching (2003) added an additional control for the study of letter groups. This attempt to control for the threat to validity in which the above results could be due to differences in the identity of letters presented in each condition instead of their location within the word (Jordan, Thomas, & Patching, 2003). According to Jordan, Thomas, and Patching (2003), it is well-known that perception of letters is affected by their individual physical properties and the similarity of these properties to those of other letters in the character set. This experiment manipulated words that were anagram pairs and contained equal number of letter pairs (Jordan, Thomas, & Patching, 2003). This manipulation allows for each word and each letter pair to be presented in both degraded and non-degraded conditions (Jordan, Thomas, & Patching, 2003), allowing the study to draw conclusions about letter pairs, whether internal or external, and their effect on reading with concern for letter content (Jordan, Thomas, & Patching, 2003).

The second experiment conducted by Jordan, Thomas, and Patching (2003) used a computer software program to establish the anagram triplets in which either the initial, exterior, or interior letter pairs were degraded. Here, 24 participants were chosen from the same population as experiment one (Jordan, Thomas, & Patching, 2003). To save time the no degradation condition was excluded (Jordan, Thomas, & Patching, 2003). After reading equal passages, the participants again had to complete a comprehension quiz (Jordan, Thomas, & Patching, 2003). A within-subjects ANOVA revealed a significant effect of display condition, $F(5, 115) = 6.87$, $p < .0001$) (Jordan, Thomas, & Patching, 2003). Newman-Keuls comparison

showed no change in reading rate for each letter pair across the different passage pairs ($p > .10$) (Jordan, Thomas, & Patching, 2003). Within passage pairs reading rate with exterior letter pair degradation was slower than with initial and interior letter degradation ($p < .01$) (Jordan, Thomas, & Patching, 2003). Reading rates for internal degradation and initial degradation were not significantly different ($p < .15$) (Jordan, Thomas, & Patching, 2003). The mean accuracy for question comprehension was 89% (range = 60%-100%) and demonstrated no evidence of systematic differences ($F < 1$) (Jordan, Thomas, & Patching, 2003). Experiment two solidifies the results of experiment one which demonstrates that external letter pairs play a significant role in reading rate additionally when controlling for letter identity (Jordan, Thomas, & Patching, 2003).

Inhoff, Radach, Eiter, and Skelly (2003) disagree with the findings cited by Jordan, Thomas, and Patching (2003). Inhoff et al. (2003) contend that the lack of control over where useful information is acquired during reading in the study conducted by Jordan, Thomas, and Patching (2003), rather than differences in the orthographic consistency and the availability of word shape information, account for the discrepant effect pattern in the two studies. Inhoff et al. (2003) seem to concur, however, with Jordan, Thomas, and Patching (2003) that the evidence they provide offers a powerful incentive for theoretical developments in the domain of visual word recognition. Inhoff et al. (2003) do not concur that the exterior letters rather than the beginning letters of a para-foveally visible word assume a privileged role. Instead Inhoff et al. (2003) argue that the processing of a word during reading begins before it is fixated when beginning letters occupy a particularly favorable parafoveal location that is independent of word length. Inhoff et al. (2003) posit that the flaw in the study conducted by Jordan, Thomas, and

Patching (2003) is that knowledge of parafoveal word length cannot be used to selectively process exterior letters during the initial phase of visual word recognition.

Jordan, Thomas, Patching, and Scott-Brown (2003) responded to the assertions made by Inhoff et al. (2003) and ultimately disagreed with the claims that were made regarding the unprivileged role of exterior letters compared to beginning letters. It was argued by Jordan, Thomas, Patching, and Scott-Brown (2003) that the original study conducted by Jordan, Thomas, and Patching (2003) did not restrict where useful information is acquired during reading and that the importance of maintaining the configural and orthographic characteristics of words were stressed. Furthermore, the study Jordan, Thomas, and Patching (2003) did not attempt to restrict the linguistic properties of manipulated words, but instead suggested exterior letters are easier to locate and process before other letters in words. The study did not distinguish between foveal and parafoveal processing. Ultimately it seems that studies that use parafoveal previews, similar to the study conducted by Inhoff et al. (2003), provide an important contribution; however, other techniques and paradigms are required to reveal the full role of letter pairs in reading (Jordan, Thomas, Patching, & Scott-Brown, 2003).

Rayner, White, Johnson, and Liversedge (2006) questioned whether letter location was important in reading and composed an assessment where college students were asked to read 80 sentences in which letters were transposed. The transpositions effected either the internal letters, beginning letters, or end letters. For example the word *solve*: *slove, oslve,* and *sloev*. The student's eye movements were recorded via a Fourward Technology Dual Purkinje eye tracker (Rayner et al., 2006). Rayner et al. (2006) noted that comprehension questions were asked after 30% of the sentences, and while readers were able to answer the questions with high accuracy, 50% of the students indicated that there were several words they did not understand.

Rayner et al. (2006) noted that the base reading rate for sentences that were not transposed was 255 words per minute (wpm), and that all variations involving letter transpositions resulted in a decrement. Rayner et al. (2006) found that when internal letters were transposed, the reading rate was 227 wpm, an 11% decrement in reading speed. However, Rayner et al. (2006) also noted that when the transpositions involved the exterior letters of words, reading rate was 189 wpm, resulting in a 26% decrement. These findings seem to indicate that the order of exterior letters of a word play a preferential role when reading compared to the order of interior letters.

Johnson and Eisler (2012) lists five word studies that support the conclusion that exterior letters play a privileged role in reading:

1. Priming studies indicate that lexical decision times and naming latencies are shorter when participants are first primed with the word's exterior letters than when primed with the word's interior letters. Furthermore, recall for briefly presented words is greater when participants are primed with their exterior letters than with two interior letters.
2. The exterior letters of briefly-presented letter strings are reported more accurately than letters in interior positions. Importantly, these effects are also found when words are used as target stimuli.
3. Responses to exterior letters are faster and more accurate than responses to interior letters on letter search tasks where participants are asked to detect whether or not a cued letter is within a letter string. Furthermore, when participants are asked to determine whether a presented word matches a pre-specified target word, search

latencies for detecting differences are faster for changes at the first and last letter position than for changes at interior locations.

4. Individuals with Letter-Position Dyslexia make more migration errors at interior letter positions than at exterior letter positions.
5. Orthographic and transposed-letter neighborhood effects differ as a function of letter position. Specifically, orthographic neighborhood effects are weaker at external letter positions than at internal positions, and transpositions that involve the first and last letter of the word cause more disruption to word recognition processes than transpositions of interior letters. (p. 377)

Johnson and Eisler (2012) conducted four experiments to determine why the first and last letters of words are more important than the interior letters during reading. In each experiment participants read sentences containing words with transposed letters occurring at the beginning of the word, near the middle of the word, or at the end of the word (Johnson & Eisler, 2012). The study involved four parts. The first involved 80 sentences designed with either beginning transpositions, internal transpositions, ending transpositions, or no transpositions (control group) (Johnson & Eisler, 2012). The participant read the sentences and then pressed a button to move on to the next sentence. Comprehension testing was done after 33% of the sentences to ensure the participants were reading for accuracy. Mean participant comprehension was 94% with range of 81%-100%. Sentences that contained internal transpositions led to longer reading times than sentences without transpositions. The longest reading times were found among transpositions at the beginning of the word (Johnson & Eisler, 2012).

The second portion of the study by Johnson and Eisler (2012) was the same as the first, but also included eye-tracking methodology to add additional processing measures beyond

simply total sentence reading time. The second portion included the 80 sentences which had one of the following conditions: control, beginning, internal, and end transpositions (Johnson & Eisler, 2012). The eye tracker methods analyzed whether the differential effects of transposition position occurred either early in processing (first fixation duration), late in processing (gaze duration and total time), or both (Johnson & Eisler, 2012). Eye movements were monitored using a high-speed camera and infrared illuminator to sample and record the position of the reader's eye every millisecond. Data analysis centered on total number of fixations and total sentence reading time. In regards to both total number of fixations and total sentence reading time there was a significant effect in sentences that contained transpositions when compared with sentences that did not contain transpositions (Johnson & Eisler, 2012). Beginning and ending transpositions were found to require the greatest number of fixations and the longest total sentence reading time (Johnson & Eisler, 2012).

The third portion of their study the authors sought to decrease the amount of lateral inference that interior letters receive by adding a space to each side of them (Johnson & Eisler, 2012). While the same 80 sentences used in experiments one and two were included, the spacing of the letters were different. Sentences were either presented with normal spacing or where an extra space was inserted between each letter within every word. There was also only one space between words (example: t h e c a t r a n u p t h e t r e e). Target words were again included to determine eye fixation. Again, the participants completed reading comprehension after 33% of the sentences.

The mean comprehension score was 95% (range 86%-100%). A significant effect of spacing condition was found, readers spent longer time on sentences that did not contain normal spacing (Johnson & Eisler, 2012). Once again readers spent more time and made greater eye

fixations on sentences that contained internal transpositions versus sentences without transpositions (Johnson & Eisler, 2012). Less time was spent with fewer fixations on internal versus beginning transpositions.

There was no significant difference between ending transpositions and internal transpositions in regards to fixation or reading time (Johnson & Eisler, 2012). Spacing conditions did cause a significant interaction in regard to beginning versus internal transpositions. In normal spacing conditions readers spent less total reading time and made fewer fixations on internal transpositions as compared with transpositions of the last two letters (Johnson & Eisler, 2012). In equal spacing conditions these were opposite. Internal transpositions took longer than ending transpositions. In contrast, when comparing internal letter transposition to beginning transposition, internal transposition required less time and fewer fixations in both the normal and equal spacing groups. Participants found the equal spacing condition to be very difficult, suggesting that word boundaries are clearly important in reading (Johnson & Eisler, 2012).

The fourth portion of their study sought to determine if the importance of initial or beginning letters simply arises from their physical proximity to the parafovea or if they are important for a reason of higher-level processing or intrinsic understanding (Johnson & Eisler, 2012). In this experiment the participants were asked to read from right-to-left instead of left-to-right. The word order also flowed in the right-to-left direction, letter order direction remained the same (example: stairs the up ran cat the). Manipulating directionality this way places the initial letters of a word farthest away from the parafovea (Johnson & Eisler, 2012). The authors theorize that if the privileged role of initial letters is simply from the location in the parafovea no

differences would be noted among beginning versus internal transpositions (Johnson & Eisler, 2012).

The same 80 sentences were again used including a target word with mean comprehension scores of 94% (range 85%-98%) (Johnson & Eisler, 2012). Readers were found to make more fixations and required longer amounts of time on sentences with internal transpositions versus those with no transpositions. Internal transpositions required fewer fixations and less total reading time than both beginning and ending transpositions (Johnson & Eisler, 2012).

These results indicate that the first letter of a word has a privileged role over interior letters regardless of the degree of lateral interference it receives or its location in the parafovea (Johnson & Eisler, 2012). This suggests that it is intrinsically related to how one processes, stores, or accesses lexical information (Johnson & Eisler, 2012). Furthermore, the last letter of a word is more important than interior letters when it receives less lateral interference and when its parafoveal location is close to the fovea (Johnson & Eisler, 2012).

White, Johnson, Liversedge, and Rayner (2008) also conducted a study involving the transposition of words and found that the longer reading times for transposed text are likely to arise largely due to difficulty with attaining understanding of individual words, rather than simply a failure to identify words at all. The study conducted by White et al. (2008) observed participants' eye movements and recorded them as they read sentences with words containing transposed adjacent letters. Transpositions were either external or internal and at either the beginning or end of the words (White et al., 2008).

The results showed disruption for words with transposed letters compared to the normal baseline condition, ($p < .01$). A 2x2 ANOVA was carried out for the four transposed conditions

(White et al., 2008). Longer total sentence reading times, longer forward and regressive fixation durations, and more forward and regressive fixations were found among external transpositions compared with internal transpositions ($p < .01$) (White et al., 2008). These findings show that the external letters are more critical for word recognition when compared with internal letters (White et al., 2008). The greatest disruption was observed for word-initial transpositions. Word-beginning transpositions were more significantly disruptive than word-ending transpositions ($p < .05$) (White et al., 2008). For total sentence reading time, transposition of the external-ending letters caused more disruption than both internal-beginning transpositions ($p < .001$) and internal-ending transpositions ($p < .001$) (White et al., 2008).

White et al. (2008) found that the positions of the first letters of a word are more critical than the ending letters of the word for letter position encoding during reading. Additionally, external ending transpositions were more important than internal transpositions, suggesting that external letters have a privileged role relative to internal letters during word identification (White et al., 2008).White et al. (2008) ultimately concluded that external letter transpositions lead to more disruptions than internal transpositions and beginning transpositions lead to more disruptions than ending transpositions.

Paterson et al. (2014) conducted an experiment to examine the importance of anagrammatical errors in word recognition and whether it varies across age groups or reading skill level. Anagrammatical errors are those such as mistaking *pirates* as *parties*. Paterson et al. (2014) suggests anagrammatical errors occur because readers use letter position flexibly during word recognition. Paterson et al. (2014) compared anagrams which either required only internal letter transpositions or both interior and exterior transpositions. The results indicate that the first letter of a word has a privileged role over interior letters regardless of the degree of lateral

interference it receives or its location in the parafovea (Paterson et al., 2014) . These findings suggest that it is intrinsically related to how one processes, stores, or accesses lexical information. Furthermore, the last letter of a word is more important than interior letters when it receives less lateral interference or when its parafoveal location was close to the fovea.

Participants included 28 developing readers aged eight-10 and 28 skilled adult readers (age 18-30) (Paterson et al., 2014). Appropriate reading level for each age group was determined via the Burt Word Reading Test and the Nelson-Denny reading test (Paterson et al., 2014). This study included 160 words with four to seven letters, each chosen from the Children's Printed Word Database (Paterson et al., 2014). The test also contained 20 pairs of interior anagrams (e.g. bread, beard) and 20 pairs of interior/exterior anagrams (e.g. benign, being) were also included (Paterson et al., 2014). Participants were tested individually (Paterson et al., 2014). The stimulus word was displayed for three seconds and then removed (Paterson et al., 2014). The participant was instructed to read the word aloud as accurately and timely as possible into a microphone (Paterson et al., 2014). Error and response time were both recorded (Paterson et al., 2014). Response time corresponded to the time taken to begin articulating a word after stimulus onset (Paterson et al., 2014). According to Paterson et al. (2014), this technique is an especially sensitive method of measuring word naming difficulty.

Response times were analyzed using a linear mixed effects model, and a logistic mixed-effects model was used to analyze error data (Paterson et al., 2014). Reading skill was found to be significant (Paterson et al., 2014). Developing readers had significantly slower responses than skilled adult readers ($p < .05$) (Paterson et al., 2014). Skilled readers also had fewer errors than developing readers ($p < .001$) (Paterson et al., 2014). Word type and type of transposition were also found to be significant ($p < .001$, $p < .01$ respectively) (Paterson et al., 2014). No

significant three way interaction between word type, transposition type, and reading skill level was found ($p < .50$) (Paterson et al., 2014). Response times were found to be slower for interior anagrams when compared with non-anagram control words, but not for words requiring the transposition of both the final letter and interior letters of words in both developing and skilled readers (Paterson et al., 2014). Error rates increased in developing readers significantly based on word type ($p < .001$) and transposition type ($p < .001$) (Paterson et al., 2014). The error rate for interior anagrams was 17%, whereas for interior/exterior anagrams the error rate was only 6% (Paterson et al., 2014). The rate of error for non-anagram words was 4% (Paterson et al., 2014).

Paterson et al. (2014) concludes that developing readers are generally slower and error prone in reading than skilled adult readers. This finding is consistent with prior research. In both groups of readers, response times, when compared with control words, were not significantly different for interior/exterior anagrams but were for interior anagrams (Paterson et al., 2014). Paterson et al. (2014) concludes that anagrams only involving interior transpositions are more difficult for readers. Interior/exterior anagrams were not found to produce a statistically significant increase in response time for readers in both groups which indicates that readers show sensitivity to the privileged role of exterior letters for word recognition (Paterson et al., 2014). Developing readers also had fewer errors in interior/exterior transpositions (Paterson et al., 2014). Paterson et al. (2014) notes that this pattern of effects suggests that presentation of an interior/exterior anagram activates the lexical representation for the presented word but not its anagrammatical counterparts and so causes little interference to the processing of the presented word, for both skilled and developing readers. Paterson et al. (2014) also concludes the similarity in use of letter position by developing and skilled adult readers in the present research runs contrary to the lexical tuning hypothesis and challenges the view that there is a

developmental trajectory in the specification of letter position. In fact, the manner in which letter position is used by developing readers is very similar to adult skilled readers in this study (Paterson et al., 2014). Paterson et al. (2014) goes on to say that flexibility in the use of letter position may be a pervasive characteristic of word recognition that is established early in the process of learning to read and thereafter shows little developmental change. Finally, Paterson et al. (2014) states that the indication already is that end state skilled use of letter position, including the privileged role of exterior letters, is established early in the process of learning to read.

Reasoning for the Prevalence of Exterior Letters in Word Recognition

While several studies have indicated that the first letter in a word deserves preferential treatment, not all seek to explain why. The study by McCandliss, Beck, Sandak, and Perfetti (2003) focused on students of deficits in decoding proficiency, word identification, phonemic awareness, and reading comprehension. The study found that students with deficits did possess some decoding abilities and that decoding the first letter of a word was more easily mastered than other letter positions. McCandliss et al. (2003) also demonstrated that decoding attempts were more accurate at the onset of the word location. McCandliss et al. (2003) found that the region of letters in a word had a significant effect on decoding ability ($p < .0001$). The study concluded that being able to identify the first letters in a word indicates partial understanding of the alphabetic principles, but not complete.

McCandliss et al. (2003) further demonstrated that alphabetic decoding is central in reading development because of the role that decoding plays in self-teaching. The self-teaching framework asserts that full alphabetic decoding allows children to find a close approximation of the proper pronunciation for unknown words and assists in forming more accurate and refined

representations of words they have seen before (McCandliss et al., 2003). Additionally, the study demonstrates that the decoding skills themselves increase as children gain additional experience with alphabetic decoding skills via reading experience.

McCandliss et al. (2003) question whether being able to decode the first letter in a word is an easier task, and theorize that children give up on decoding the other letters in a word. The study seems to indicate that while students may successfully decode the first letter, they do not necessarily apply the same reasoning to decode the additional letters in the word. By coupling the first letter and the last letter in this present study, it may draw on student's limited decoding abilities of the first letter, combined with use of the last letter in hopes to encourage the reader to apply the same principles he/she used on the first letter to the last.

McCandliss et al. (2003) conclude that being proficient in word decoding skills enhances reading comprehension. The study indicates that readers with poor growth in reading skills have a fundamental failure to engage in full alphabetic decoding. By directly targeting decoding, improvements in all reading skills were noted.

Summary

The information processing theory can easily be tied to the theoretical framework of color coding exterior letters during reading by addressing its connection to mental cognition, sensory input, and how the brain processes letters when reading (Christoudoulou et al., 2014; Dimitrov et al., 2011; Miller, 2011; Schraw & McCrudden, 2009; Wichmann et al., 2002). Information processing theory's depiction of how the brain responds to patterns and colors underlies the fact that color, specifically the color blue, plays an important role in assisting struggling readers (Barron, 1996; Fiedler, 1992; Iovino et al., 1998).

These facts lead this researcher to the assumption that utilizing color to highlight the most important part of a word might aid in ones decoding and fluency capabilities. The review of the literature in this chapter largely supports the notion that exterior letters are more essential to reading fluency and comprehension than interior letters based on several parafoveal imaging studies (Foster, 1975; Humphreys et al., 1990; Johnson & Eisler, 2012; Jordan, Thomas, & Patching, 2003; McCusker et al., 1981; Patterson et al., 2014; Rayner et al., 2006; Shillcock & Monghan, 2003).

A case can also be made for the importance and need for reading interventions that do not merely prompt struggling readers to guess words based on context clues, but focus on giving students tools to phonetically decode words (McCandliss et al., 2003; Torgesen et al., 2001). A significant reading intervention could possibly take form if educators pair the effects that blue color coding patterns have on struggling readers with the importance of exterior letters when reading.

CHAPTER THREE: METHODS

Overview

Chapter Three describes the research design as well as lists the research questions and hypotheses. This chapter addresses the number of participants, demographic information regarding the participants, and the setting where the research took place. Chapter Three concludes with the procedures that were taken when this experiment was executed and how the data of the experiment was analyzed.

Design

A true experimental, -posttest-only control-group research design was used to determine if students' fluency, ability to decode real words, and ability to decode pseudowords were affected based upon the color coding of exterior letters of a word. The independent variable is the presence of color coded exterior letters in a leveled high frequency word list. It is generally defined as applying a different color to the first and last letter of words on a leveled word list and applying a different color to the first and last letter of leveled high frequency words in a reading passage. The dependent variable is the ability of intermediate students who are below grade level in reading to decode a high frequency word list with real words and pseudowords and fluently read a leveled reading passage.

This design involved three elements: random assignment, the presence of a control group, and manipulation. The first step was to randomly assign research participants to the experimental and control groups (Gall, Gall, & Borg, 2010). The researcher administered the treatment to the experimental group and no treatment to the control group (Gall et al., 2010). In this study, the posttest that the experimental group completed was the treatment. The treatment group was assessed on a word list decoding test of words and pseudowords and reading passage

fluency test. Each test had the exterior letters colored blue. The same tests without color coded exterior letters was given to the control group. An experimental design is more rigorous because it includes random assignment to experimental and control groups (Gall et al., 2010). Random assignment in large sample groups hopes to eliminate initial differences between the experimental and control group (Gall et al., 2010). According to Gall et al. (2010) this design is preferred when there is concern that a pretest would affect the results of a posttest. A pretest in this study would lessen the internal validity in that students might familiarize themselves with the vocabulary terms on which they are being tested. This research design was chosen because it employs both a control group and a means to measure the difference that occurs in both groups via a randomized posttest only equivalent group study. A control group is an essential component in this experiment because it allowed any change in the posttest to be attributed only to the experimental treatment that was manipulated by the researcher (Gall et al., 2010). To determine the effectiveness of the intervention, the researcher verified if there was a statistical significance between the control and experimental groups. Each experiment assessed the statistical information via an independent *t* test.

Research Questions

RQ1: Is there a difference in the ability to decode real words between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level?

RQ2: Is there a difference in the ability to decode pseudowords between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level?

RQ3: Is there a difference in the reading fluency of a reading passage between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level?

Hypotheses

$H_0$1: There is no significant difference in the ability to decode real words between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level.

$H_0$2: There is no significant difference in the ability to decode pseudowords between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level.

$H_0$3: There is no significant difference in the reading fluency of a reading passage between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level.

Participants and Setting

The sampling frame in this study included 102 students from various elementary schools in a southeastern United States school district. Demographic breakdown of secondary students who are below grade level in literacy from this district is as follows: 68% of secondary students in this district scored below grade level in literacy. 18% of students who scored below grade level in literacy were Black or African American, 55% were Economically Disadvantaged, 30% were Hispanic, 21% were English Language Learners with T1/T2, and 17% were Students with Disabilities. 26% of students are below basic in literacy, while 41% are basic in literacy. The researcher elicited certain schools in this district to participate. Schools were conveniently chosen based on factors such as availability, proximity, and willingness to participate. The

socio-economic status of the students in participating schools were assessed using the school's free and reduced lunch data. This researcher observed free and reduced lunch data from the Tennessee Department of Education website. Students who were below grade level in literacy were selected randomly from various elementary schools in the district who met these criteria. Each student in this study was in fourth-grade and was chosen based on the criteria of being below grade level in literacy based on state standardized assessment data (TCAP). Participants were identified as below grade level based on being basic or below basic on TCAP results from the prior year, which is a cut score of below 71.6%. Fourth-grade students were selected because they are the first grade that has TCAP results from the previous year and, by selecting a single grade versus multiple grades, this study was able to control for age, grade, and developmental differences in students.

There were several assumptions in this research design:

- Students in both the control and experimental groups who were identified as below grade level on state standardized assessment data were accurately assessed to be below grade level.
- Each student in this study was in fourth grade
- Each student in this study was chosen based on the criteria of being below grade level in reading based on state standardized assessment data (TCAP).
- Students were randomly selected to participate in the experimental group or control group.
- No student in this test was color blind.

Participation were elicited by requesting teachers from the school to send home a parent consent form to all qualifying students. The researcher then obtained a list of the 102 students

and gave parental consent letters to teachers to send home with qualifying students. Students were asked to return a signed copy of the consent form to the teacher which was then collected by the researcher. Once permission was obtained, the participants were randomly selected from the group of qualifying students. Thus, a convenient sample was used as the means of sampling this population. After obtaining a volunteer sample, the participants were randomly assigned to either the experimental or control group. Each student was randomly assigned to either an experimental or control group by placing the names of all the students on an individual sheet of paper, putting the names in a box, and randomly pulling names from the box and placing them into one of the two groups. Using a power calculation with a statistical power of .7 at the .05 level of significance, 100-person total sample group is needed for a medium effect size in this study (Gall et al., 2010).

The testing locations were at participating schools from a district in the southeast United States. A reading specialist administered the test to students in an isolated classroom setting. The only individuals in the classroom was the test administrator and the testee. This process took four weeks to test all 102 students. Posters and signs were either taken down or covered up. The students who were selected to participate in the control group versus the experimental, for example, would have a typed, printed word list of the same words in Times New Roman, 12-point font. This word list comes from an individual test from the Houghton Mifflin (2009) diagnostic assessment (see Appendix C and D). The administrator recorded the results in individual file folders for each participant, which was then provided to the researcher upon completion.

Instrumentation

The Tennessee Comprehensive Achievement Program (TCAP) was used as an instrument in this experiment to identify students who were below grade level in reading. The literacy portion of TCAP is the state standardized test utilized to ascertain student performance and scores students in a category of Below Basic, Basic, Proficient, and Advanced. Any student who scored Basic or Below Basic on TCAP is considered below grade level in reading (TCAP, n.d.). Sanders and Horn (1995) assess the validity of standardized testing, including TCAP, and note that standardized testing renders viable, inexpensive, reliable, and valid indicators of student learning useful in the assessment of educational entities and student achievement. Standardization, according to Sanders and Horn (1995), makes it possible to generalize and to draw conclusions about the data and their implications. Therefore, TCAP was used as an instrument in this research to identify students who were below grade level in reading.

The Houghton Mifflin (2009) diagnostic assessment uses the Consortium on Reading Excellence Phonics Survey (CORE-PS) for measuring fluency and decoding. Therefore, any future reference to the assessments utilized in this study will simply be referred to as CORE-PS. CORE-PS was used to measure the dependent variables in each research question. Reutzel, Brandt, Fawson, and Jones (2014) mention evidence of the extent to which the CORE-PS meets the following psychometric criteria: test retest, internal consistency, and interrater reliability and face, content, construct, consequential, and criterion validity. Findings suggest that the CORE-PS provides an acceptably reliable and valid assessment of primary-grade students' decoding and reading phonics knowledge (Reutzel et al., 2014). Reutzel et al. (2014) note that the CORE-PS allows teachers and researchers access to theoretically grounded assessment of students' development of orthographic knowledge and word recognition. Spear and Brucker (2004) used

the CORE-PS to assess children via pre and post testing on decoding skills of both real and pseudowords. Colenbrander, Nickles, and Kohnen (2011) also conducted a study to survey the available resources for pseudoword reading skills and utilized the CORE-PS assessment. Brownell et al. (2014) employed the CORE-PS in their assessment of Special Education Teacher's learning and teaching styles.

The fluency portion of this research was measured by the CORE-PS fluency reading passage. The CORE-PS is a curriculum-based measurement (CBM) that assesses oral reading fluency (ORF). The CORE-PS underwent reliability and validity testing by Reutzel et al. (2014). A reliability of .70 or greater determines whether the measurement is acceptable (Cohen, 1988). Pearson's r correlations were studied comparing the CORE-PS instrument with oral reading fluency scores. The correlation coefficient was $K = .84$ which was found to be significant at $p < .01$ (Reutzel et al., 2014).

The control and experimental group of the fluency portion of this assessment were measured by the CORE-PS. Both groups were assessed on the fourth-grade reading level. Each student read the passage aloud while the reading coach noted errors. The fluency score was determined by calculating the number of words read correctly per minute. Students received three minutes to read the passage. The number of words the student read in three minutes minus the student's errors determined the student's total correct number of words. That number was divided by three (the number of minutes in which the student was required to read the passage) to determine the number of words correct per minute. The exterior letters of words were colored blue for the experimental group, and no letters were colored for the control group. Approximately three to five minutes was needed to explain, administer, and record the results of the fluency portion of this assessment.

The CORE-PS decoding test is an assessment that asks students to decode words from several word lists with a range of phonetic elements that progress in difficulty. The CORE-PS decoding section contains both real and pseudoword word lists. The instrument was found to be a reliable and valid measurement of decoding skills in elementary students. Regarding test-retest reliability the Pearson r correlation coefficient was found to be .98 (Reutzel et al., 2014). The internal consistency reliability was found using Cronbach's alpha and was determined to range from .95-.98 (Reutzel et al., 2014). Interrater reliability was found to be strong using the G and phi reliability coefficients regarding reading and decoding skills (G = .96, ϕ = .95) (Reutzel et al., 2014). The criterion-related validity coefficients were K = .86 (Reutzel et al., 2014).

During the CORE-PS decoding test, students were given 35 real words to read from a list that contained the following phonetic element categories: five short vowels in CVC (consonant vowel consonant) words, five short vowels, diagraphs, and –tch trigraphs, 10 short vowels and consonant blends, five long vowels, five r and l-controlled vowels, and five vowel diphthongs. The minimum raw score a student could receive was a 0/35, and the maximum raw score was 35/35.

Students were also given 35 pseudowords to read from a list that contained the following phonetic element categories: five short vowels in CVC (consonant vowel consonant) pseudowords, five short vowel pseudowords, diagraphs, and –tch trigraph pseudowords, 10 short vowels and consonant blend pseudowords, five long vowel pseudowords, five r and l-controlled vowel pseudowords, and five vowel diphthong pseudowords. The minimum raw score a student could receive was a 0/35, and the maximum raw score was 35/35. Scores from the real word assessment and pseudoword assessment were then converted to a percentage ranging from 0% to 100%. Each exterior letter of this assessment was colored blue for the treatment group. The

control group was given an identical word list assessment as the treatment group, except the exterior letters of the words of the control group's assessment were not colored. Approximately three to five minutes was needed to explain, administer, and record the results of the decoding real words and decoding pseudowords portion of this assessment. Permission to modify the CORE-PS decoding assessment and fluency assessment to include the color coding intervention is referenced in Appendix J.

Control Group	Experimental Group
tape	tape
key	key
lute	lute
paid	paid
feet	feet

Figure 3.1. Sample word list from the Houghton Mifflin (2009) diagnostic assessment.

Procedures

The district superintendent was notified via a form outlining the procedures of this experiment. His approval was secured prior to the beginning of this study and prior to IRB approval. The researcher obtained IRB approval before beginning any experimental research on students. Other individuals that received the permission request form included the principals from each school, reading coaches, and the teachers of the participants.

The students who were below grade level in TCAP were sent a parent consent form requesting permission to be a part of this study. The researcher gave teachers a consent form for students to bring home for permission to be a part of the study and the researcher collected the

consent forms the following day. Upon receiving permission from each person involved in this process, this researcher obtained IRB approval.

A reading coach was trained on the procedures for this experiment and was responsible for administering the assessment to both the experimental and control group. The training was conducted by this researcher after school in a designated classroom at the school. The training lasted one day and took approximately one hour to complete. The training covered the diagnostic assessment procedures, script, and grading of the CORE-PS.

Once permission was attained, 102 students were randomly assigned to the experimental or control groups. Each student was assigned to a number. The students were assigned to a group by placing their numbers in a container, mixing the container, drawing the number out, and placing the numbers one by one in the experimental or control group. After students were assigned to groups, one list of the names was provided to the school's reading coach indicating the students who needed to be tested.

Once the students were assigned to groups, the reading coach alternated giving the test to the treatment and control groups. The CORE-PS decoding test is an assessment that asks students to decode words from several word lists with a range of phonetic elements that progress in difficulty. Students were given 35 real words to read from a list that contained each of the following phonetic element categories: five short vowels in CVC (consonant vowel consonant) words, five short vowels, diagraphs, and –tch trigraphs, 10 short vowels and consonant blends, five long vowels, five r and l-controlled vowels, and five vowel diphthongs. The minimum raw score a student could receive was a 0/35, and the maximum raw score was 35/35. Students were also given 35 pseudowords to read from a list that contains each of the following phonetic element categories: five short vowels in CVC (consonant vowel consonant) pseudowords, five

short vowel pseudowords, diagraphs, and –tch trigraph pseudowords, 10 short vowels and consonant blend pseudowords, five long vowel pseudowords, five r and l-controlled vowel pseudowords, and five vowel diphthong pseudowords. The minimum raw score a student could receive was a 0/35, and the maximum raw score was 35/35. Scores from the real word assessment and pseudoword assessment were converted to a percentage ranging from 0% to 100%. Each exterior letter of this assessment was colored blue for the treatment group. The control group was given an identical word list assessment as the treatment group, except that the exterior letters of the words of the control group's assessment were not colored.

The control and experimental group also were assessed on the CORE-PS fluency assessment. Both groups were assessed on the fourth-grade reading level. Each student read the passage aloud while the reading coach noted errors. The fluency score was determined by calculating the number of words read correctly per minute. Students received three minutes to read the passage. The number of words the student read in three minutes minus the student's errors determined the student's total correct number of words. That number was divided by three (the number of minutes in which the student was required to read the passage) to determine the number of words correct per minute. The exterior letters of a word with three letters or more were color coded blue for the experimental group. No letters were color coded for the control group. The test administrator was trained on the procedures for administering this assessment one day prior to examining students by receiving a copy of the CORE-PS assessment which includes instructions for test administration and grading under each task (See Appendix B and Appendix G).

Data Analysis

The statistical procedure for measuring the results of the first research question, is there a difference in the ability to decode words between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level, was an independent *t* test. The null hypothesis was that there will be no difference in the ability to decode words between those who are presented with color coded exterior letters and those who are not presented with color coded exterior letters in intermediate students who are below grade level. Thus, the study was a two-tailed independent *t*-test. The *t*-test is an appropriate choice because it provides a rough comparison between two means (Zhang, 2009). The mean of each group (M) was determined after turning each student's raw score into a percentage and then averaging the scores together. The independent *t* test can be used to determine if two sets of data are significantly different from each other (Gall et al., 2010), which was the aim of this study. This test is appropriate because there was one independent nominal variable, the coloring of exterior letters of a word, two groups, the treatment and control groups, and one dependent ratio variable, the ability to accurately decode words.

The statistical procedure for measuring the results of the second research question, is there a difference in the ability to decode pseudowords between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level, was also an independent *t* test. Like the first research question, this experiment sought to analyze if the there was a significant difference between the control group and treatment group in decoding pseudowords, and thus was two-tailed. The *t* test was chosen because there was one independent nominal variable, the coloring of

exterior letters of target words, two groups, the treatment and control groups, and one dependent ratio variable, decoding pseudowords.

The statistical procedure for measuring the results of the third research question, is there a difference in the reading fluency of a reading passage between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level, was an independent *t* test. Like the other research questions, this experiment sought to analyze if the there was a significant difference between the control group and treatment group in reading fluency scores, and thus was two-tailed. The *t* test was chosen because there was one independent nominal variable, the coloring of exterior letters of target words, two groups, the treatment and control groups, and one ratio dependent variable, reading fluency.

The sample required a minimum of 50 control (n1 = 50) and 50 experimental (n2 = 50) participants for a total population of at least 100 (N), which was determined by setting a statistical power of .7 at the .05 level of significance for a medium effect size in this study (Gall et al., 2010). The degrees of freedom (df) were found using the formula: (n1-1) + (n2-1) and should be at least 98. The t-value (t) measured the size of the difference relative to the variation in sample data. A $p < .05$ level of significance was used for all analyses in the study to determine if the null hypotheses could be rejected. The effect size was calculated using Cohen's *d* (1998). Cohen's *d* is the difference between two means divided by the average of their standard deviations (SD). It evaluates the degree in standard deviation units that the mean scores of the test variables differ. The further the *d* value is away from 0, the larger the effect size becomes. The effect size was interpreted based on the following: below 0.5 was considered

small, 0.5 to 0.8 medium, and an effect size greater than or equal to 0.8 was considered large (Cohen, 1988).

There were four primary assumptions with the independent samples *t* test. The first was the assumption of independence which assumes that participant scores are independent and not systematically related to other participants' scores. The second assumption in this study was the assumption of homogeneity of variance which determines whether the variances in scores for two samples differ significantly from each other (Gall et al., 2010). Since the two sets of scores were obtained from independent samples, the test for homogeneity of independent variances, Levene's test, was used in this study to compare the differences between variances in two sets of scores obtained from independent samples (Gall et al., 2010). The third assumption was that of level of measurement. The assumption for this *t* test was that the scale of measurement applied to the data collected followed a ratio scale. The fourth assumption was that of normality. When a normal distribution is assumed, it indicates that the sample of observations will closely resemble normal distribution of the whole population. The Kolmogorov-Smirnov test of normality was used to determine if the levels of the independent variable were statistically normal. Non-significant results above 0.05 indicate the assumption was tenable and that normality could be assumed. Outliers were identified via box plots. Outliers that are noted were first examined to ensure the result was not entered in error. After ensuring no error present, the Grubb's test was used to confirm the data point was indeed an outlier. Extreme outliers were then considered for deletion if the remainder of the data was normally distributed. Statistics including M, SD, N, n, df, t value, power, and significance level were also reported.

CHAPTER FOUR: FINDINGS

Overview

Chapter Four describes the findings as well as lists the research questions and hypotheses. This chapter lists the descriptive statistics for each research question, results from the independent *t* test, analyzes the assumptions of each research question, and explains their effect size. Chapter Four also contains charts that depict the descriptive statistics for each research question, graphs that show each test's distribution, and box plots that note outliers for each test.

Research Questions

RQ1: Is there a difference in the ability to decode real words between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level?

RQ2: Is there a difference in the ability to decode pseudowords between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level?

RQ3: Is there a difference in the reading fluency of a reading passage between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level?

Null Hypotheses

$H_0$1: There is no significant difference in the ability to decode real words between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level.

$H_0$2: There is no significant difference in the ability to decode pseudowords between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level.

$H_0$3: There is no significant difference in the reading fluency of a reading passage between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level.

Descriptive Statistics

A total of 102 students were tested in measurements of decoding real words, decoding pseudowords, and reading fluency. A total of 51 of the participants were in the control group for the real word assessment (N = 51, M = 92.33, SD = 7.974) and 51 of the participants were in the treatment group for the real word assessment (N = 51, M = 94.75, SD = 6.645).

Table 4.1

Descriptive Statistics for Decoding Real Words

	N	Mean	Standard Deviation	Standard Error Mean
Control Group	51	92.33	7.974	1.117
Treatment Group	51	94.75	6.645	.930

A total of 51 of the participants were in the control group for the pseudoword assessment (N = 51, M = 78.76, SD = 14.381) and 51 of the participants were in the treatment group for the pseudoword assessment (N = 51, M = 84.31, SD = 12.393).

Table 4.2

Descriptive Statistics for Decoding Pseudowords

	N	Mean	Standard Deviation	Standard Error Mean
Control Group	51	78.76	14.381	2.014
Treatment Group	51	84.31	12.393	1.735

A total of 51 of the participants were in the control group for the fluency assessment (N = 51, M = 92.12, SD = 30.983) and 51 of the participants were in the treatment group for the fluency assessment (N = 51, M = 103.94, SD = 28.590).

Table 4.3

Descriptive Statistics for Reading Fluency

	N	Mean	Standard Deviation	Standard Error Mean
Control Group	51	92.12	30.983	4.338
Treatment Group	51	103.94	28.590	4.003

Results

Null Hypothesis One

$H_0$1: There is no significant difference in the ability to decode real words between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level.

An independent *t* test was used to analyze the first null hypothesis that assessed whether the presence of coloring the exterior letters of words effected decoding real words. This test was appropriate because there was one independent nominal variable, the coloring of exterior letters

of a word, two groups, the treatment and control groups, and one dependent ratio variable, the ability to accurately decode words. For the first hypothesis, the dependent variable, the ability to decode real words, was measured using scores obtained from the CORE-PS decoding test with color coding exterior letters of each word or not color coding exterior letters of each word serving as the independent variable.

Assumption testing. The first assumption is the assumption of independence which assumes that participant scores are independent and not systematically related to other participants' scores. The second assumption in this study is the assumption of homogeneity of variance which determines whether the variances in scores for two samples differ significantly from each other (Gall et al., 2010). Since the two sets of scores are obtained from independent samples, the test for homogeneity of independent variances, Levene's test, was used in this study to compare the differences between variances in two sets of scores obtained from independent samples (Gall et al., 2010). The significance level for Levene's test was .234 which is larger than the alpha level of .05 indicating that the assumption of equal variance has not been violated.

The third assumption was that of level of measurement. The assumption for this *t* test was that the scale of measurement applied to the data collected followed a ratio scale. The fourth assumption was that of normality. When a normal distribution is assumed, it indicates that the sample of observations will closely resemble normal distribution of the whole population. The Kolmogorov-Smirnov test of normality was used to determine if the levels of the independent variable were statistically normal. Non-significant results above 0.05 indicate the assumption was tenable and that normality can be assumed. For decoding real words, the results of the Kolmogorov-Smirnov test determined a significance level of .000.

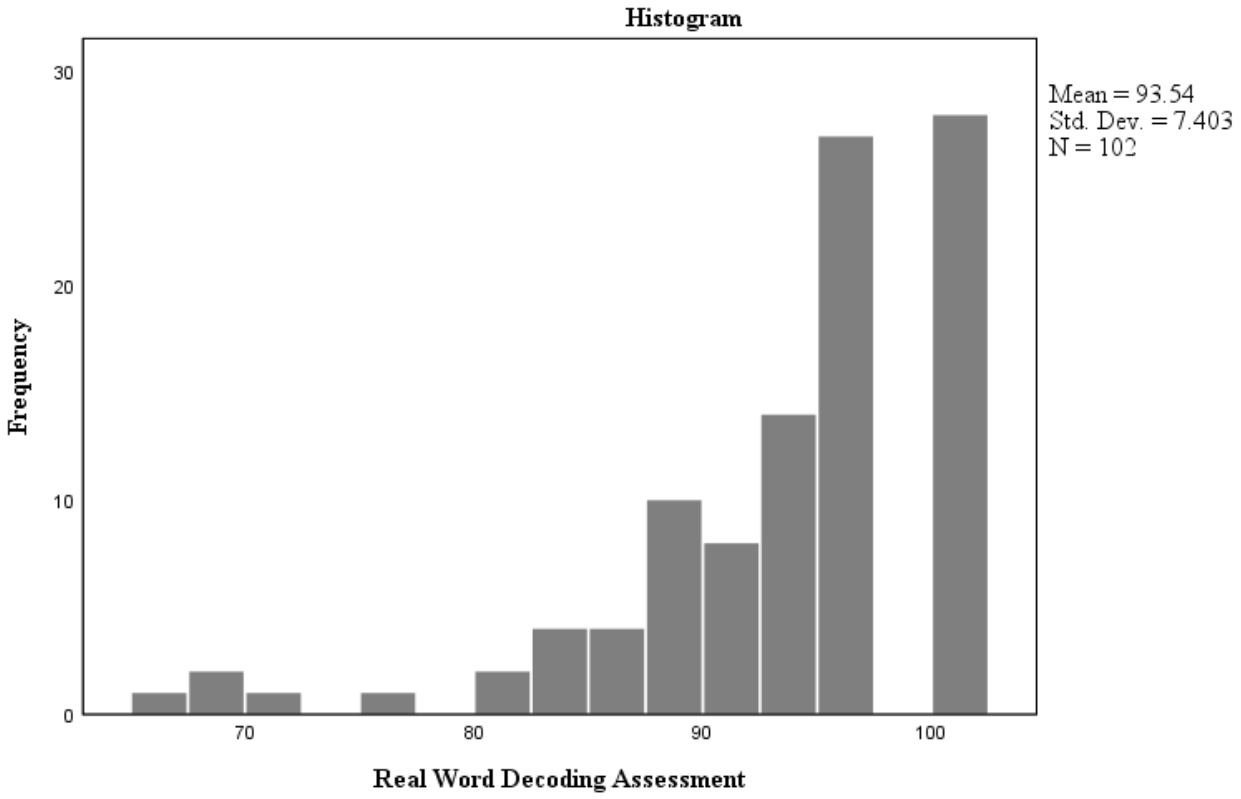

Figure 4.1. Histogram for real word decoding.

Outliers were then identified using a box plot. Outliers were examined to ensure the result was not entered in error. After ensuring no error present, the Grubb's test was used to confirm the data point was indeed an outlier. Utilizing Grubb's test at the upper 2.5% level of significance for a sample size of 102 participants the significance level was found to be 3.390 (Grubbs & Beck, 1972). Based on the z-score for real words one extreme outlier was identified with a significance value of 3.72. This data was removed, and the Kolmogorov-Smirnov test was calculated a second time, but the significance level remained the same at .000. Since the sample size in this study was large (greater than 40), the central limit theorem justifies using parametric procedures even when the data are not normally distributed (Elliot & Woodward, 2007).

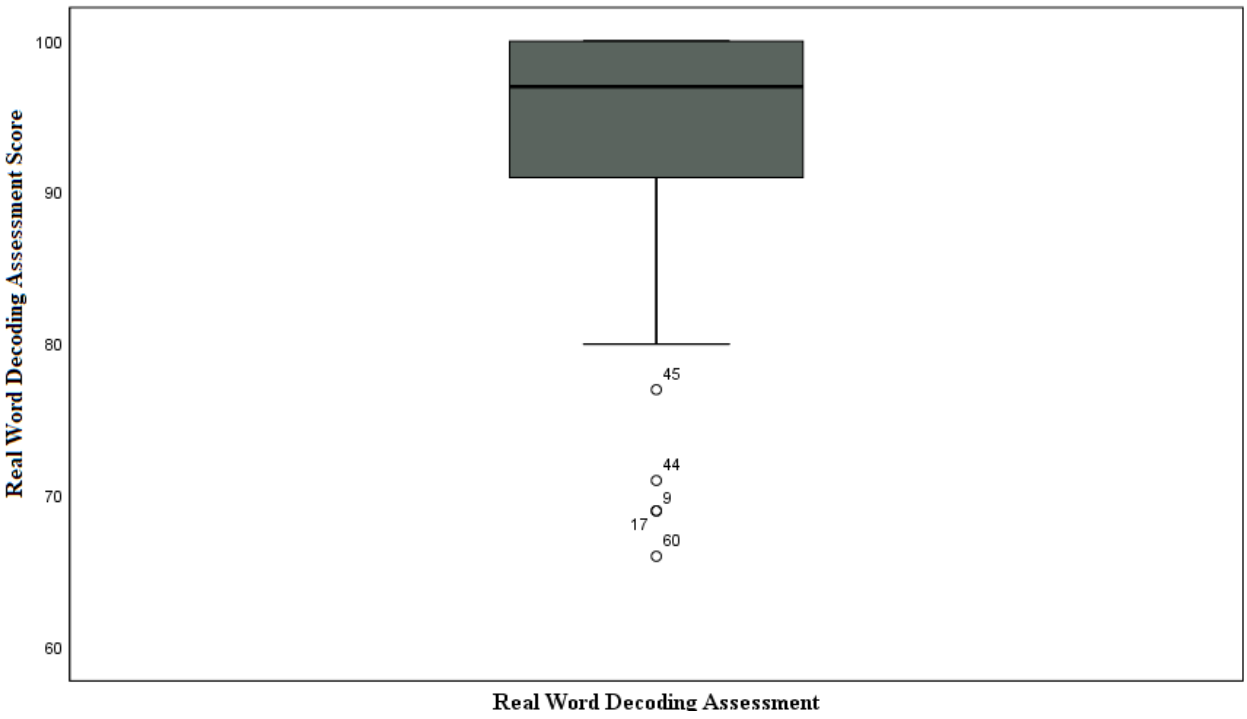

Figure 4.2. Box plot for real word decoding.

Analysis. An independent *t* test was conducted to determine if a difference existed between the mean decoding real word scores of students without the exterior letters of each word colored blue (control group) and students with exterior letters of each word colored blue (treatment group). There was no statistically significant difference between the mean scores of the control group (n = 51, M = 92.33, SD = 7.974) and treatment group (n = 51, M = 94.75, SD = 6.645), t (102) = -1.659, p = .1. The effect size was calculated using Cohen's *d.* The effect size was interpreted based on the following: lower than 0.5 was considered small, 0.5 to 0.8 was considered medium, and an effect size greater than or equal to 0.8 was considered large (Cohen, 1988). The effect size of this study was determined to be -0.33 which is small. The 95% confidence interval was -5.295 to 0.472. The researcher failed to reject the null hypothesis.

Null Hypothesis Two

$H_0$2: There is no significant difference in the ability to decode pseudowords between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level.

An independent *t* test was used to analyze the second null hypothesis that assessed whether the presence of coloring the exterior letters of words effected decoding pseudowords. This test was appropriate because there was one independent nominal variable, the coloring of exterior letters of a pseudoword, two groups, the treatment and control groups, and one dependent ratio variable, the ability to accurately decode pseudowords. For the second hypothesis, the dependent variable, the ability to decode pseudowords, was measured using scores obtained from the CORE-PS decoding test with color coding exterior letters of each pseudoword or not color coding exterior letters of each pseudoword serving as the independent variable.

Assumption testing. The first assumption is the assumption of independence which assumes that participant scores are independent and not systematically related to other participants' scores. The second assumption in this study is the assumption of homogeneity of variance which determines whether the variances in scores for two samples differ significantly from each other (Gall et al., 2010). Since the two sets of scores were obtained from independent samples, the test for homogeneity of independent variances, Levene's test, was used in this study to compare the differences between variances in two sets of scores obtained from independent samples (Gall et al., 2010). The significance level for Levene's test was .317 which is larger than the alpha level of .05 indicating that the assumption of equal variance has not been violated.

The third assumption was that of level of measurement. The assumption for this *t* test was that the scale of measurement applied to the data collected followed a ratio scale. The fourth assumption was that of normality. When a normal distribution is assumed, it indicates that the sample of observations will closely resemble normal distribution of the whole population. The Kolmogorov-Smirnov test of normality was used to determine if the levels of the independent variable were statistically normal. Non-significant results above 0.05 indicate the assumption is tenable and that normality can be assumed. For decoding pseudowords, the results of the Kolmogorov-Smirnov test determined a significance level of .000.

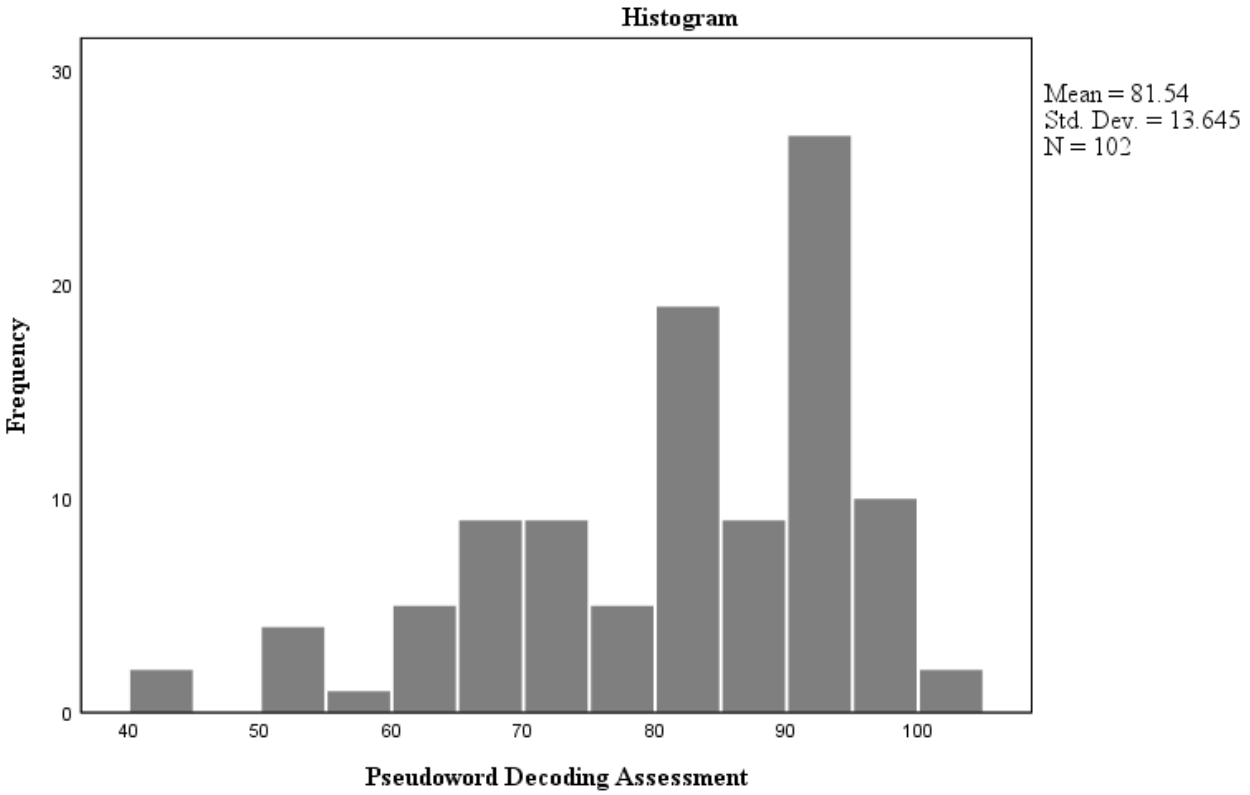

Figure 4.3. Histogram for pseudoword decoding.

Outliers were then identified using a box plot. Outliers were examined to ensure the result was not entered in error. After ensuring no error present, the Grubb's test was used to confirm the data point was indeed an outlier. Utilizing Grubb's test at the upper 2.5% level of

significance for a sample size of 102 participants the significance level was found to be 3.390 (Grubbs & Beck, 1972). Based on the z-score for pseudowords there were no extreme outliers. Since the sample size in this study was large (greater than 40), the central limit theorem justifies using parametric procedures even when the data are not normally distributed (Elliot & Woodward, 2007).

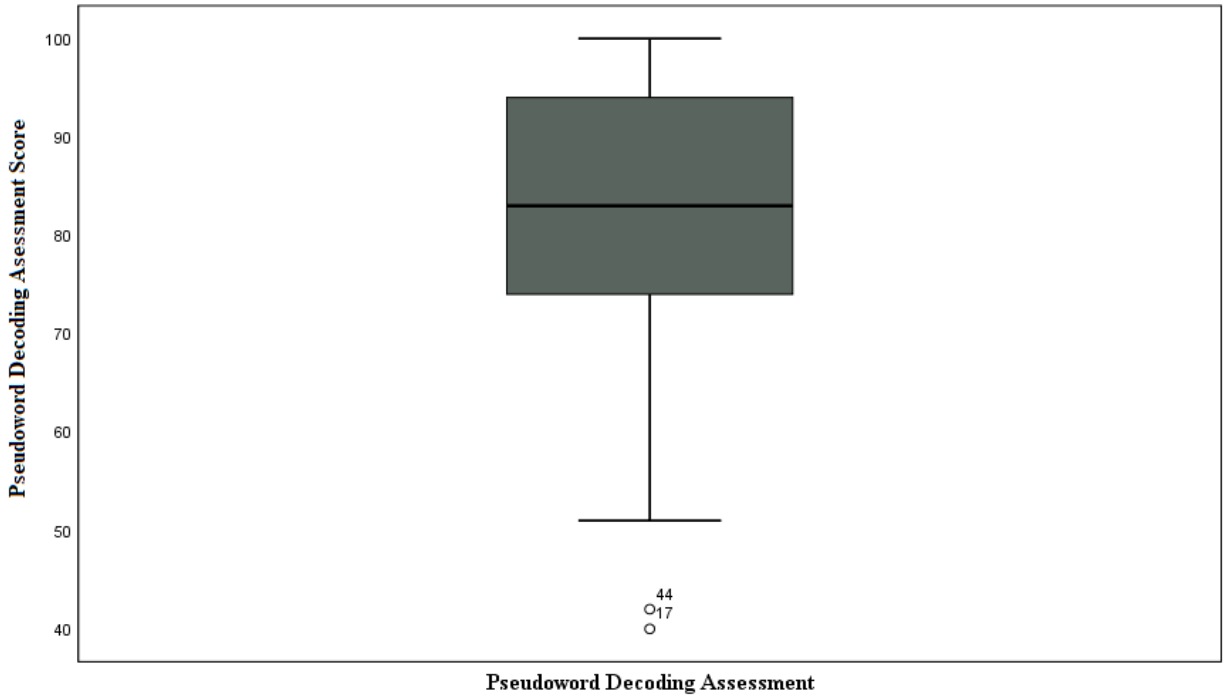

Figure 4.4. Box plot for pseudoword decoding.

Analysis. An independent *t* test was conducted to determine if a difference existed between the mean decoding pseudoword scores of students without the exterior letters of each word colored blue (control group) and students with exterior letters of each word colored blue (treatment group). There was a statistically significant difference between the mean scores of the control group (n = 51, M = 78.76, SD = 14.381) and treatment group (n = 51, M = 84.31, SD = 12.393), t (102) = -2.087, p = .039. The effect size was calculated using Cohen's d. The effect size was interpreted based on the following: lower than 0.5 was considered small, 0.5 to 0.8 was

considered medium, and an effect size greater than or equal to 0.8 was considered large (Cohen, 1988). The effect size of this study was determined to be -0.41 which is small. The 95% confidence interval was -10.823 to -.275. The researcher rejected the null hypothesis.

Null Hypothesis Three

$H_0$3: There is no significant difference in the reading fluency of a reading passage between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level.

An independent *t* test was used to analyze the second null hypothesis that assessed whether the presence of coloring the exterior letters of words effected reading fluency. This test was appropriate because there was one independent nominal variable, the coloring of exterior letters of words, two groups, the treatment and control groups, and one dependent ratio variable, the ability to read a passage with fluency. For the third hypothesis, the dependent variable, the ability to read a passage fluently, was measured using scores obtained from the CORE-PS fluency assessment with color coding exterior letters of each word or not color coding exterior letters of each word serving as the independent variable.

Assumption testing. The first assumption was the assumption of independence which assumes that participant scores are independent and not systematically related to other participants' scores. The second assumption in this study was the assumption of homogeneity of variance which determines whether the variances in scores for two samples differ significantly from each other (Gall et al., 2010). Since the two sets of scores were obtained from independent samples, the test for homogeneity of independent variances, Levene's test, was used in this study to compare the differences between variances in two sets of scores obtained from independent

samples (Gall et al., 2010). The significance level for Levene's test was .751 which was larger than the alpha level of .05 indicating that the assumption of equal variance has not been violated.

The third assumption was that of level of measurement. The assumption for this *t* test was that the scale of measurement applied to the data collected followed a ratio scale. The fourth assumption was that of normality. When a normal distribution is assumed, it indicates that the sample of observations will closely resemble normal distribution of the whole population. The Kolmogorov-Smirnov test of normality was used to determine if the levels of the independent variable are statistically normal. Non-significant results above 0.05 indicate the assumption was tenable and that normality can be assumed. For reading fluency, the results of the Kolmogorov-Smirnov test determined a significance level of .044.

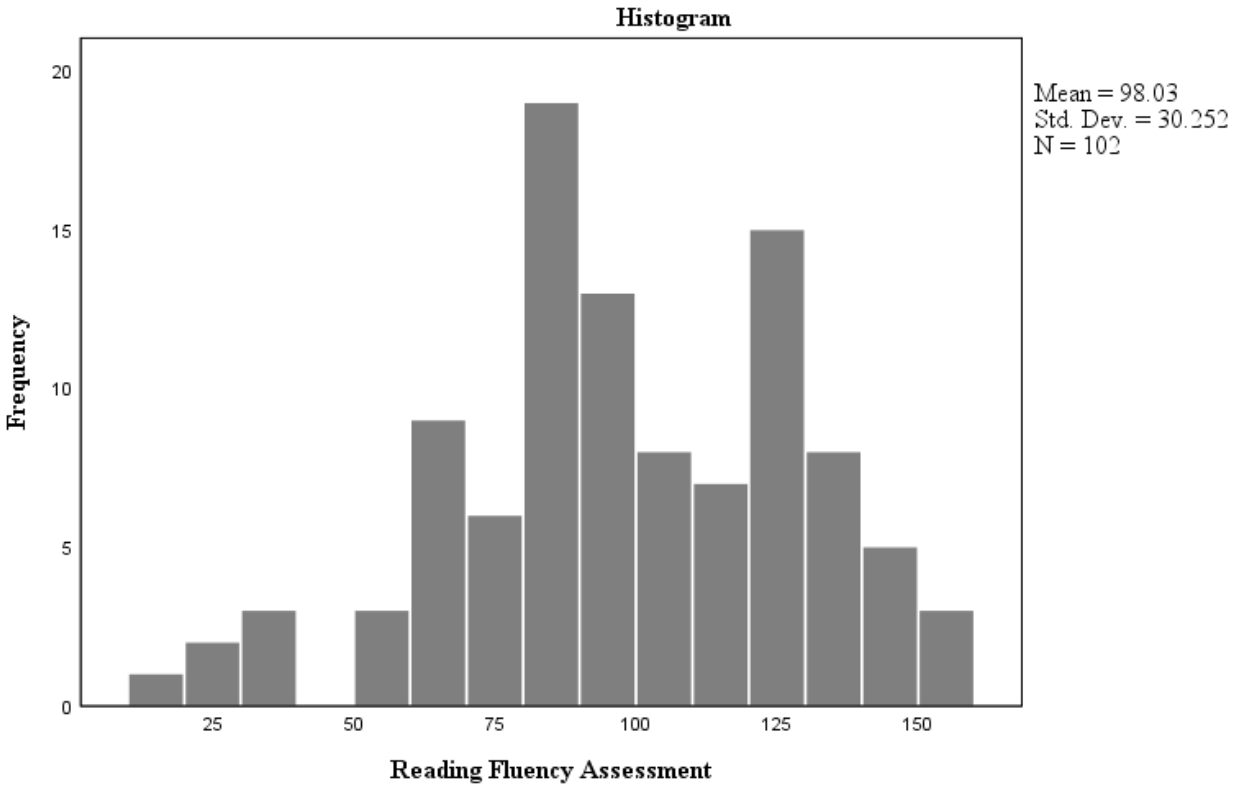

Figure 4.5. Histogram for reading fluency.

Outliers were then identified using a box plot. Outliers were examined to ensure the result was not entered in error. After ensuring no error present, the Grubb's test was used to confirm the data point was indeed an outlier. Utilizing Grubb's test at the upper 2.5% level of significance for a sample size of 102 participants the significance level was found to be 3.390 (Grubbs & Beck, 1972). Based on the z-score for pseudowords there were no extreme outliers. An inspection of the histogram shows a nearly normal distribution which supports continuing with the *t* test. Furthermore, since the sample size in this study was large (greater than 40), the central limit theorem justifies using parametric procedures even when the data are not normally distributed (Elliot & Woodward, 2007).

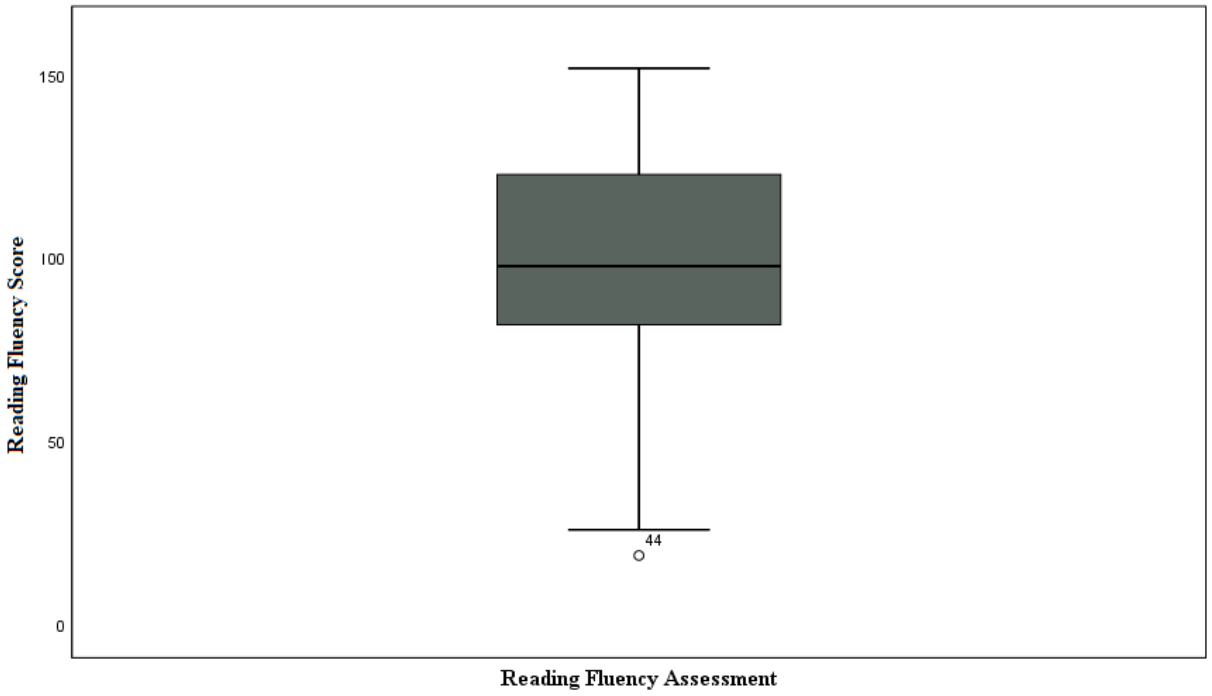

Figure 4.6. Box plot for reading fluency.

Analysis. An independent *t* test was conducted to determine if a difference existed between the mean reading fluency scores of students without the exterior letters of each word

colored blue (control group) and students with exterior letters of each word colored blue (treatment group). There was a statistically significant difference between the mean scores of the control group (n = 51, M = 92.12, SD = 30.983) and treatment group (n = 51, M = 103.94, SD = 28.590), t (102) = -2.003, p = .048. The effect size was calculated using Cohen's d. The effect size was interpreted based on the following: lower than 0.5 was considered small, 0.5 to 0.8 was considered medium, and an effect size greater than or equal to 0.8 was considered large (Cohen, 1988). The effect size of this study was determined to be -0.4 which was small. The 95% confidence interval was -23.536 to -.111. The researcher rejected the null hypothesis.

CHAPTER FIVE: CONCLUSIONS

Overview

Since little was known about coloring the exterior letters of words as an intervention for struggling readers, the current study sought to contribute to the existing field of research by evaluating the effectiveness of such an intervention. A real-word decoding, pseudoword decoding, and fluency assessment was given to fourth grade students who were below grade level in literacy to determine if coloring the first and last letters of words blue would increase word decoding and reading fluency. Chapter Five provides a discussion of the researcher's findings, the researcher's implications, limitations, and the researcher's recommendations for future research.

Discussion

The purpose of this true experimental, posttest-only control-group design was to determine if the color coding of exterior letters affected the fluency and decoding ability among fourth grade students who were below grade level in reading. A reading intervention that utilized color was chosen because of the positive effects that color has on processing information, patterns, and highlighting important details (Barron, 1996; Fiedler, 1992; Iovino et al., 1998). Exterior letters were chosen for color coding because exterior letters seem to have a preferential role in the reading process (Foster, 1975; Humphreys et al., 1990; Johnson & Eisler, 2012; Jordan, Thomas, & Patching, 2003; McCusker et al., 1981; Patterson et al., 2014; Rayner et al., 2006; Shillcock & Monghan, 2003).

Research Question One

RQ1: Is there a difference in the ability to decode real words between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level?

$H_0$1: There is no significant difference in the ability to decode real words between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level.

The null hypothesis was analyzed, and the researcher failed to reject the null hypothesis. Scores on the decoding assessment were high and negatively skewed, indicating that students may have already been familiar with the words used in this assessment. Unlike decoding unfamiliar words that rely on the use of phonics to assist in the word identification process (Torgesen et al., 2001), familiar words are often accessed and recognized by orthographic processing (Aaron et al., 1999). If students from both the treatment group and control group were familiar with these words, they may not have used a letter-by-letter decoding procedure to read the words in the assessment (Aaron et al., 1999). Since the intervention was designed to assist students in decoding the phonological features of words, students who were already familiar with these words may not have benefited from the intervention.

Although the researcher failed to reject the null hypothesis, results indicated that mean scores for the treatment group were higher when compared to the control group. These results might suggest that some students from the treatment group, who were not familiar with the words in this study, were assisted by the exterior letter color coding intervention. This suggestion supports the research that indicates color has a positive effect on processing information, patterns, and highlighting important details (Barron, 1996; Fiedler, 1992; Iovino et

al., 1998). Wichmann et al. (2002) mention that color plays a highly specialized role in certain image segmentation tasks. Perhaps coloring the primary parts of the words in this study aided the students in the treatment group in segmenting the words so each word could be easily decoded.

Jordan, Thomas, and Patching (2003) show that exterior letter pairs play a major role in single word recognition. In a study that visually degraded letter pairs in three positions of words (initial, exterior, and interior), reading times for initial and interior degradation did not differ ($p = .74$); however, when exterior letters were degraded reading rate was found to be significantly slower ($p < .01$) (Jordan, Thomas, & Patching, 2003). These results indicate that the role of exterior letters in single-word recognition is of greater significance than interior letter pairs. Students in the treatment group may have benefited from having this preferential part of a word highlighted resulting in the mean scores for the treatment group ($N = 51$, $M = 94.75$, $SD = 6.645$) being slightly higher than the control group ($N = 51$, $M = 92.33$, $SD = 7.974$), $t\ (102) = -1.659$, $p = .1$.

Research Question Two

RQ2: Is there a difference in the ability to decode pseudowords between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level?

$H_0$2: There is no significant difference in the ability to decode pseudowords between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level.

The null hypothesis was analyzed, and the researcher rejected the null hypothesis. These findings support the information process theory, which describes the way in which information

pertaining to mental stimulation and responses are represented and processed by humans (Proctor & Vu, 2006), the positive effects that color has on processing information, (Barron, 1996; Fiedler, 1992; Iovino et al., 1998), and the preferential role of exterior letters in the reading process (Foster, 1975; Humphreys et al., 1990; Johnson & Eisler, 2012; Jordan, Thomas, & Patching, 2003; McCusker et al., 1981; Patterson et al., 2014; Rayner et al., 2006; Shillcock & Monghan, 2003).

Paterson et al. (2014) compared anagrams which either required only internal letter transpositions or both interior and exterior transpositions. Response times were found to be slower for interior anagrams when compared with non-anagram control words, but not for words requiring the transposition of both the final letter and interior letters of words in both developing and skilled readers (Paterson et al., 2014). Error rates increased in developing readers significantly, based on word type ($p < .001$) and transposition type ($p < .001$) (Paterson et al., 2014). The error rate for interior anagrams was 17%, whereas for interior/exterior anagrams the error rate was only 6% (Paterson et al., 2014). The rate of error for non-anagram words was 4% (Paterson et al., 2014). The results indicate that the first and last letter of a word has a privileged role over interior letters (Paterson et al., 2014). Students in the treatment group may have benefited from having the privileged part of a word colored by aiding readers in the decoding process.

Hall et al. (2013) analyzed colored filter systems and children with reading disabilities and concluded that children with reading disabilities like dyslexia often struggle with visual stress. The results indicate that color reduces visual stress and note that further research into the effects of color and reading will need to be done (Hall et al., 2013). Perhaps the blue color in the

exterior letters assisted students from the treatment group who suffer from visual stress associated with reading disabilities.

Unlike the real word assessment that was analyzed in $H_0$1, which may have been affected by student's familiarity with the words of that assessment, pseudowords are designed to determine a student's understanding of grapheme-phoneme relations and phonemic awareness and do not allow for students to rely on sight word knowledge in reading (Cummings et al., 2011). According to England and Gibson (2015), pseudowords are essential in testing reading decoding and fluency because pseudowords control for random word recognition. The statistically significant difference between the mean scores of the control group (n = 51, M = 78.76, SD = 14.381) and treatment group (n = 51, M = 84.31, SD = 12.393), t (102) = -2.087, p = .039 of the pseudoword assessment not only supports the use of a decoding intervention that employs color coding exterior letters of words, the results may also give further credibility to the explanation that the researcher failed to reject $H_0$1 because that assessment relied on orthographic processing instead of word decoding.

Research Question Three

RQ3: Is there a difference in the reading fluency of a reading passage between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level?

$H_0$3: There is no significant difference in the reading fluency of a reading passage between those who are presented with color coded exterior letters and those who are not presented color coded exterior letters in intermediate students who read below grade level.

The null hypothesis was analyzed, and the researcher rejected the null hypothesis. These findings support the information process theory, which describes the way in which information

pertaining to mental stimulation and responses are represented and processed by humans (Proctor & Vu, 2006), the positive effects that color has on processing information, (Barron, 1996; Fiedler, 1992; Iovino et al., 1998), and the preferential role of exterior letters in the reading process (Foster, 1975; Humphreys et al., 1990; Johnson & Eisler, 2012; Jordan, Thomas, & Patching, 2003; McCusker et al., 1981; Patterson et al., 2014; Rayner et al., 2006; Shillcock & Monghan, 2003).

According to Christodoulou et al. (2014), impaired reading fluency can be attributed to several factors including temporal processing impairments within the brain, impaired phonological awareness that occurs even before the onset of reading instruction, and impaired naming speed for lists of stimuli. The improved fluency performance of students in the treatment group might be attributed to the intervention's effect on mental processes which is supported by the information processing theory (Miller, 1956).

In a study by Iovino et al. (1998) where colored overlays were placed over reading passages in an attempt to improve visual stress in students with reading disabilities, it was revealed that blue overlays significantly improved reading comprehension accuracy relative to reading without an overlay, $F(1, 56) = 4.72$, $p = .03$. The percentage of children who showed improved performance with a blue transparency was 57% (Iovino et al., 1998). Perhaps the blue color in the exterior letters of the intervention assisted students from the treatment group who suffer from visual stress associated with reading disabilities.

Johnson and Eisler (2012) found that both the first and last letters of a word have a privileged role over interior letters of words. Johnson and Eisler (2012) suggest that exterior letters are important because they are related to how the mind either organizes lexical information or retrieves that lexical information. Shetreet and Friedmann (2011) note that the

first and last letters in the word are more easily identified for readers with letter position dyslexia. Scaltritti and Balota (2013) mention that the exterior letters of a word are more noticeable. The statistically significant difference between the mean scores of the control group (n = 51, M = 92.12, SD = 30.983) and treatment group (n = 51, M = 103.94, SD = 28.590), t (102) = -2.003, p = .048 may have been the result of the colored exterior letters assisting the student in accessing lexical information by highlighting the most important part of the word, the exterior letters.

Implications

This study contributed to the body of research surrounding instructional interventions for struggling readers, the effectiveness of color coding strategies, and the primacy of exterior letters of words in word decoding. Although the first and last letters of a word have a privileged role over interior letters (Peterson et al. 2014), exterior letters may not be salient enough for struggling readers to assimilate exterior letter phonemic clues, which are essential for word decoding. One way to improve the effectiveness of exterior letter presentation is to make the first and last letter more obvious with a color coding system. This study demonstrated the effectiveness of instructional reading strategies that visually emphasize the exterior letters of words. The intervention procedure could be modified in a variety of ways to assist struggling readers.

Nelson et al. (2014) verified that many students who struggle to read texts continue to display phonics errors, especially when encountering unknown words, regardless of grade or age. Nelson et al. (2014) suggests a more comprehensive reading program that includes Word Attack strategies for older students who struggle with reading. According to Nelson et al. (2014), this instruction should focus on blending phonemes, breaking words down into subunits, and

focusing on the particular problems a student might be struggling with in word decoding. Coloring the exterior letters of words could also be implemented with other Word Attack strategies to remediate students who failed to reach early reading milestones.

The easy application and cost effectiveness of this intervention will make it suitable for educators to implement this technique into classroom instruction. Curriculum developers would merely need to edit the words of a passage and apply color to the first and last letter of words. Teachers could make vocabulary flash cards and simply color the exterior letters of words differently for struggling readers. Sight words could be taught using this technique using different colored magnetic letters, markers, paint, or tangible manipulatives. Anchor charts could also be posted throughout the classroom using this strategy as an intervention for struggling readers.

Limitations

This study had numerous limiting factors. A threat to the internal validity was compensatory rivalry by the control group. It is possible that control group participants in this study performed beyond their usual level because they perceive that they are in competition with the experimental group (Gall et al., 2010). The students in this study knew that the purpose of this study was to determine the effectiveness of coloring the exterior letters of words, therefore they could deduce if they were in the group that was receiving the treatment by the presence or absence of colored exterior letters in their assessment. If this phenomenon occurs, the difference between the experimental treatment and control groups on the posttest can be attributed to the control group's unusual motivation rather than to the treatment effects (Gall et al., 2010).

Another threat to the internal validity was resentful demoralization of the control group. The control group in this study could have become discouraged if the control students perceived

that the experimental group was receiving a desirable treatment that was being withheld from the control group (Gall et al., 2010). As a result, the performance on the posttest might be lower than normal (Gall et al., 2010). Furthermore, the experimental treatment might appear to be better than it is, because the difference between the posttest scores of the experimental and control groups were artificially increased by the demoralization of the control group (Gall et al., 2010).

Both threats to internal validity are ultimately attributed by the mere fact that individuals were aware they were participating in an experiment which engenders the Hawthorne effect (Gall et al., 2010). When experimenters give students special attention, this factor alone, rather than the treatment, may cause a change in student behavior (Gall et al., 2010). The researcher therefore cautions generalizations about effectiveness of this intervention to individuals who were not present in this study.

A threat to external validity in this study was that of population validity. This study included 102 students from various elementary schools in a southeastern United States school district. The results of this study can only be generalized to the population from which the sample was drawn (Gall et al., 2010).

Another threat to external validity that of ecological validity. The novelty of the experimental treatment might be effective simply because it is different from the instruction that participants normally receive (Gall et al., 2010). If this is true, the results of the experiment have low generalizability because the treatment's effectiveness is likely to erode as the novelty wears off (Gall et al., 2010).

Recommendations for Future Research

The results of this study led to numerous recommendations for future research. First, it would be beneficial to test students using a real word decoding assessment that is more difficult. Scores on the decoding assessment were high and negatively skewed, indicating that students may have already been familiar with the words used in this assessment. Since the intervention was designed to assist students in decoding the phonological features of words, students who were already familiar with these words may not have benefited from the intervention. A future test that contains more rigorous words that the students are not familiar with might improve the results of this intervention.

A second recommendation for future research should be to evaluate the effectiveness of coloring the exterior letters of words on diverse populations. Researchers could conduct a multivariate analysis that controls for the effects of coloring exterior letters on gender, English speakers of other languages, socioeconomic status, and various learning disabilities. Observing the effects of this intervention on more than one statistical outcome would more definitively determine which population would benefit from the intervention.

A third recommendation for future research should be to evaluate the effectiveness of color coding various morphemes, affixes, stems, roots, syllables, and other morphological elements of words. Nelson et al. (2014) note the effectiveness of Word Attack Skills that break words down into subunits and blend phonemes; however, future research should demonstrate if color is an effective strategy for remediating these Word Attack Skills in struggling readers.

Rvachew, Nowak, and Cloutier (2004) note that students who have poor phonemic awareness often find it difficult to segment words into onset and rime. The onset is the initial phonological unit of a word, and the rime is the letters that follow the onset. Future research

should consider evaluating the effectiveness of an onset-rime color coding intervention. This could be accomplished by comparing the results of a pretest-posttest pseudoword assessment that color codes the onset-rimes of words.

A threat to external validity in this study was that of population validity. This researcher assessed an experimentally accessible population that was within driving distance. Future research should assess the effectiveness of coloring exterior letters as a reading intervention in various geographical locations to enhance the generalizability of the research findings.

Another recommendation for future research should be to conduct a longitudinal study of the effectiveness of this intervention. This study contained an ecological threat to its external validity due to the novelty of the intervention. Since this study was the initial tryout, the results have low generalizability (Gall et al., 2010). Follow up studies with the participants would determine if the treatment's effectiveness erodes as the novelty wears off.

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APPENDICES

APPENDIX A: Scoring and Analysis Summary Form

Removed for copyright purposes.

APPENDIX B: Decoding Test Summary Form

Removed for copyright purposes.

APPENDIX C: Control Group Decoding Test

Removed for copyright purposes.

Removed for copyright purposes.

APPENDIX D: Experimental Group Decoding Test

Removed for copyright purposes.

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APPENDIX E: Fluency Recording Form

Name _____ Date _____

Diagnostic Assessment
SECTION TWO

Say: I want you to read aloud part of a book called *The Midnight Fox*. It is about Tom, a boy who spends the summer on his Aunt Millie and Uncle Fred's farm. Tom has been watching a beautiful black fox and her cub in the woods all summer. Now Uncle Fred wants to get rid of the fox because she has been eating Aunt Millie's chickens. In this part of the story, Tom goes with Uncle Fred and his dog Happ to look for the fox.

Time the oral reading. Place an X on last word read at 3 minutes. Have student finish that sentence and then read silently to end.

The Midnight Fox

by Betsy Byars

	Cumulative Words
Uncle Fred crossed the creek in one leap—the water	10
was that low now—and stepped up the bank. Silently I	21
followed. "Fox tracks," he said, and with the muzzle of his	32
gun he pointed down to the tiny imprints in the sand. I had	45
not even noticed them.	49
If I had hoped that Uncle Fred was not going to be able	62
to find the black fox, I now gave up this hope once and for	76
all. What it had taken me weeks and a lucky accident to	88
accomplish, he would do in a few hours.	96
"The fox must be up there in the woods," I said eagerly,	108
knowing she was not, or that if she was, she had gone there	121
only to make a false track.	127
"Maybe," Uncle Fred said.	131
"Let's go there then," I said and I sounded like a	142
quarrelsome, impatient child.	145
"Don't be in too big a hurry. Let's look a bit." . . .	156
I said again, "Why don't we go up in the woods and	168
look. I think the fox's up there."	175

Name _____ Date _____

Diagnostic Assessment
SECTION TWO

The Midnight Fox (continued)

Cumulative Words

"I'm not looking for the fox," he said. "We could chase 186
that fox all day and never get her. I'm looking for the den." He 199
walked a few feet farther and then paused. He knelt and held 211
up a white feather. "One of Millie's chickens," he said. "Hasn't 222
been enough breeze in a week to blow it six inches. 234
Come on." 236

We walked on along the creek bank in the direction I had 248
feared. I was now overtaken by a feeling of utter hopelessness. 259
My shoulders felt very heavy and I thought I was going to 271
be sick. Usually when something terrible happened, I would 280
get sick, but this time I kept plodding along right behind 291
Uncle Fred. I could not get it out of my mind that the fox's 305
life might depend on me. I stumbled over a root, went down on 317
my knees, and scrambled to my feet. Uncle Fred looked back 328
long enough to see that I was still behind him and then 341
continued slowly, cautiously watching the ground, the woods, 349
everything. Nothing could escape those sharp eyes. 356

Suddenly we heard, from the woods above, the short high 366
bark I knew so well. The black fox! Uncle Fred lifted his head 379
and at once Happ left the creek bank and dashed away into the 391
woods. . . . 393

We walked up the field and then back to the creek. 404
We crossed the creek and while we were standing there 414
Happ returned. He was hot, dusty, panting. He lay down in 425
the shallow water of the creek with his legs stretched out 436
behind him and lapped slowly at the water. 444

Name _____ Date _____

Diagnostic Assessment
SECTION TWO

The Midnight Fox (continued)

	Cumulative Words
"Happ didn't get the fox," I said. Every time I spoke,	455
I had the feeling I was breaking a rule of hunting, but I	468
could not help myself. As soon as I had said this, we heard	481
the bark of the fox again. This time it seemed closer than	493
before. Uncle Fred shifted his gun in his hand, but he did	505
not raise it. Happ, however, rose at once to the call, dripping	517
wet, still panting from his last run. Nose to the ground, he	529
headed for the trees.	533
The sound of his baying faded as he ran deeper into the	545
woods. I knew the fox had nothing to fear from the hound. The	557
fox with her light quick movements could run from this	568
lumbering dog all day. It was Uncle Fred, moving closer and	579
closer to the den with every step, who would be the end of the	592
black fox.	595

Fluency

Words Correct Per Minute

Words in 3 mins.	_____
Minus errors	- _____
Total correct	_____
Divide by 3	÷3
WCPM	= _____

APPENDIX F: Control Group Fluency Test

Name _____ Date _____

Diagnostic Assessment
SECTION TWO

The Midnight Fox

by Betsy Byars

Uncle Fred crossed the creek in one leap—the water was that low now—and stepped up the bank. Silently I followed. "Fox tracks," he said, and with the muzzle of his gun he pointed down to the tiny imprints in the sand. I had not even noticed them.

If I had hoped that Uncle Fred was not going to be able to find the black fox, I now gave up this hope once and for all. What it had taken me weeks and a lucky accident to accomplish, he would do in a few hours.

"The fox must be up there in the woods," I said eagerly, knowing she was not, or that if she was, she had gone there only to make a false track.

"Maybe," Uncle Fred said.

"Let's go there then," I said and I sounded like a quarrelsome, impatient child.

"Don't be in too big a hurry. Let's look a bit." . . .

I said again, "Why don't we go up in the woods and look. I think the fox's up there."

Name _____ Date _____

The Midnight Fox (continued)

"I'm not looking for the fox," he said. "We could chase that fox all day and never get her. I'm looking for the den." He walked a few feet farther and then paused. He knelt and held up a white feather. "One of Millie's chickens," he said. "Hasn't been enough breeze in a week to blow it six inches. Come on."

We walked on along the creek bank in the direction I had feared. I was now overtaken by a feeling of utter hopelessness. My shoulders felt very heavy and I thought I was going to be sick. Usually when something terrible happened, I would get sick, but this time I kept plodding along right behind Uncle Fred. I could not get it out of my mind that the fox's life might depend on me. I stumbled over a root, went down on my knees, and scrambled to my feet. Uncle Fred looked back long enough to see that I was still behind him and then continued slowly, cautiously watching the ground, the woods, everything. Nothing could escape those sharp eyes.

Suddenly we heard, from the woods above, the short high bark I knew so well. The black fox! Uncle Fred lifted his head and at once Happ left the creek bank and dashed away into the woods. . . .

We walked up the field and then back to the creek. We crossed the creek and while we were standing there Happ returned. He was hot, dusty, panting. He lay down in the shallow water of the creek with his legs stretched out behind him and lapped slowly at the water.

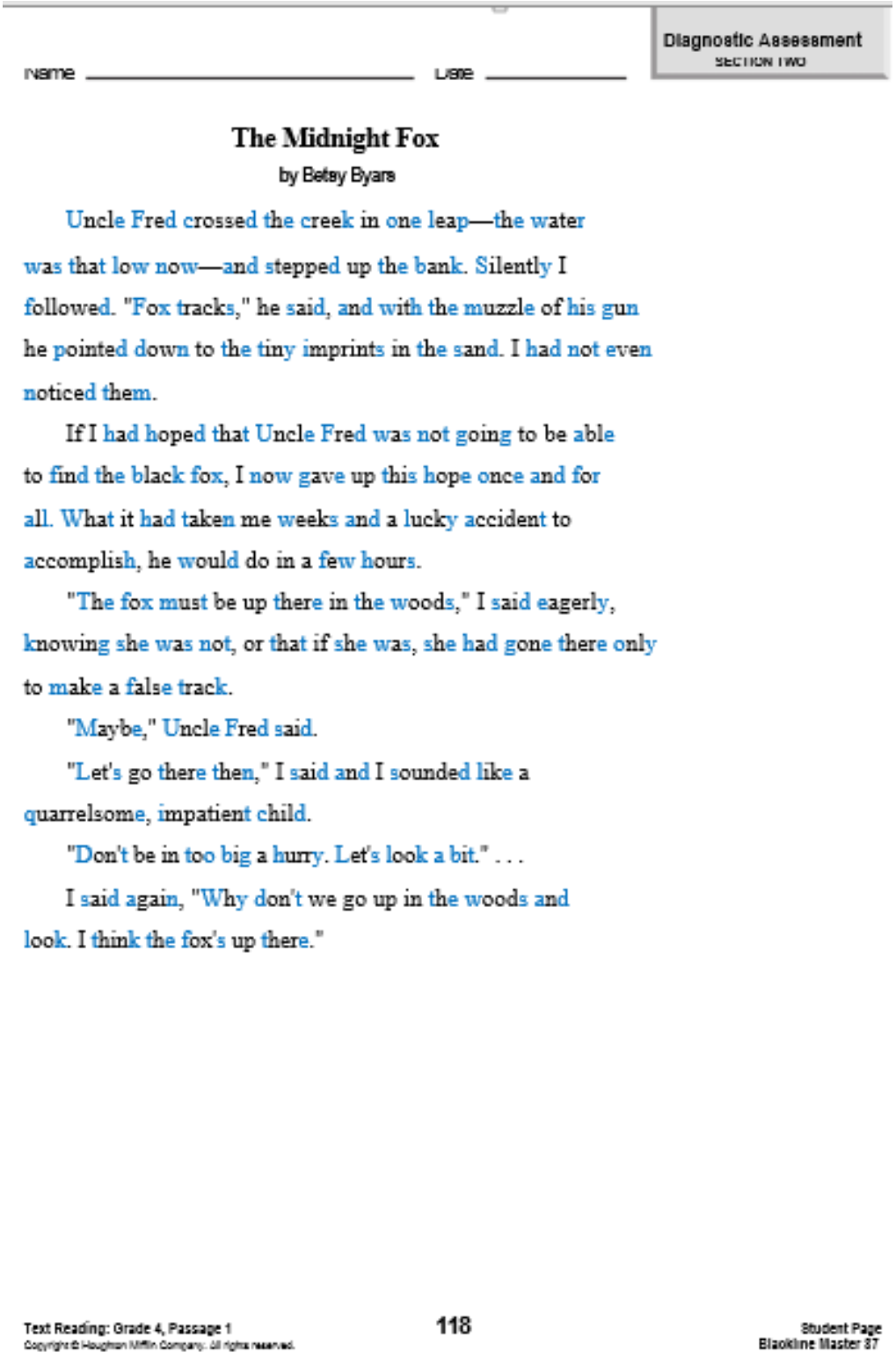
Name _____ Date _____

The Midnight Fox (continued)

"Happ didn't get the fox," I said. Every time I spoke, I had the feeling I was breaking a rule of hunting, but I could not help myself. As soon as I had said this, we heard the bark of the fox again. This time it seemed closer than before. Uncle Fred shifted his gun in his hand, but he did not raise it. Happ, however, rose at once to the call, dripping wet, still panting from his last run. Nose to the ground, he headed for the trees.

The sound of his baying faded as he ran deeper into the woods. I knew the fox had nothing to fear from the hound. The fox with her light quick movements could run from this lumbering dog all day. It was Uncle Fred, moving closer and closer to the den with every step, who would be the end of the black fox.

APPENDIX G: Experimental Group Fluency Test



Name _____ Date _____

Diagnostic Assessment
SECTION TWO

The Midnight Fox

by Betsy Byars

Uncle Fred crossed the creek in one leap—the water was that low now—and stepped up the bank. Silently I followed. "Fox tracks," he said, and with the muzzle of his gun he pointed down to the tiny imprints in the sand. I had not even noticed them.

If I had hoped that Uncle Fred was not going to be able to find the black fox, I now gave up this hope once and for all. What it had taken me weeks and a lucky accident to accomplish, he would do in a few hours.

"The fox must be up there in the woods," I said eagerly, knowing she was not, or that if she was, she had gone there only to make a false track.

"Maybe," Uncle Fred said.

"Let's go there then," I said and I sounded like a quarrelsome, impatient child.

"Don't be in too big a hurry. Let's look a bit." . . .

I said again, "Why don't we go up in the woods and look. I think the fox's up there."

Text Reading: Grade 4, Passage 1

118

Student Page
Blackline Master 37

Name _____ Date _____

The Midnight Fox (continued)

"I'm not looking for the fox," he said. "We could chase that fox all day and never get her. I'm looking for the den." He walked a few feet farther and then paused. He knelt and held up a white feather. "One of Millie's chickens," he said. "Hasn't been enough breeze in a week to blow it six inches. Come on."

We walked on along the creek bank in the direction I had feared. I was now overtaken by a feeling of utter hopelessness. My shoulders felt very heavy and I thought I was going to be sick. Usually when something terrible happened, I would get sick, but this time I kept plodding along right behind Uncle Fred. I could not get it out of my mind that the fox's life might depend on me. I stumbled over a root, went down on my knees, and scrambled to my feet. Uncle Fred looked back long enough to see that I was still behind him and then continued slowly, cautiously watching the ground, the woods, everything. Nothing could escape those sharp eyes.

Suddenly we heard, from the woods above, the short high bark I knew so well. The black fox! Uncle Fred lifted his head and at once Happ left the creek bank and dashed away into the woods. . . .

We walked up the field and then back to the creek. We crossed the creek and while we were standing there Happ returned. He was hot, dusty, panting. He lay down in the shallow water of the creek with his legs stretched out behind him and lapped slowly at the water.

Name_____ Date_____

Diagnostic Assessment
SECTION TWO

The Midnight Fox (continued)

"Happ didn't get the fox," I said. Every time I spoke, I had the feeling I was breaking a rule of hunting, but I could not help myself. As soon as I had said this, we heard the bark of the fox again. This time it seemed closer than before. Uncle Fred shifted his gun in his hand, but he did not raise it. Happ, however, rose at once to the call, dripping wet, still panting from his last run. Nose to the ground, he headed for the trees.

The sound of his baying faded as he ran deeper into the woods. I knew the fox had nothing to fear from the hound. The fox with her light quick movements could run from this lumbering dog all day. It was Uncle Fred, moving closer and closer to the den with every step, who would be the end of the black fox.

APPENDIX H: Permission to use Houghton Mifflin Diagnostic Assessment

Houghton Mifflin Harcourt School Publishers

Attn: Permissions

6277 Sea Harbor Drive

Orlando, FL 32887-6777

To whom it may concern,

My name is Edward Kirby, and I am working on a Ed. D. Doctoral Dissertation in Curriculum and Instruction from Liberty University. My research is focusing on the significance exterior letters play in reading, and I am attempting to conduct a reading intervention that color codes the first and last letter of a word.

In order to assess this intervention, I am hoping to use the Houghton Mifflin Diagnostic Assessment decoding and fluency test to determine if the intervention is significant. The control group will be given a normal version of the Houghton Mifflin Diagnostic Assessment while the treatment group will be given a version of the Houghton Mifflin Diagnostic Assessment that has been modified with the exterior letters colored blue. A copy of both the test and modified test that students would be taking is included in this packet.

In order to proceed in my research, I will need permission from Houghton Mifflin Harcourt School Publishers to modify the assessment and utilize the findings of this intervention in my research. Please respond at your earliest convenience on this matter.

Sincerely,

Edward Kirby

Doctoral Candidate, Liberty University

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November 28, 2016

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Liberty University
[redacted]

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[redacted]

Michael Kahn
IP Licensing Assistant

Penguin Random House

4 December 2016

Edward Kirby
[redacted]

Re: *The Midnight Fox* by Betsy Byars - Web Request # 30009399

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1. It is understood and agreed that the Excerpt will be used to assess the reading skills of 110 children. Fifty-five children will take the assessment with all of the letters of the words in the Excerpt colored black. Fifty-five children will take the assessment with the first and last letters of each word colored blue and the rest of the letters colored black.

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APPENDIX I: IRB Approval

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August 25, 2017

Edward M. Kirby
IRB Approval 2868.082517: The Effect of Color Coding Exterior Letters of Words on Reading Fluency and Decoding Ability in Intermediate Students who Read Below Grade Level

Dear Edward M. Kirby,

We are pleased to inform you that your study has been approved by the Liberty University IRB. This approval is extended to you for one year from the date provided above with your protocol number. If data collection proceeds past one year, or if you make changes in the methodology as it pertains to human subjects, you must submit an appropriate update form to the IRB. The forms for these cases were attached to your approval email.

Thank you for your cooperation with the IRB, and we wish you well with your research project.

Sincerely,

[redacted]

G. Michele Baker, MA, CIP
Administrative Chair of Institutional Research
The Graduate School

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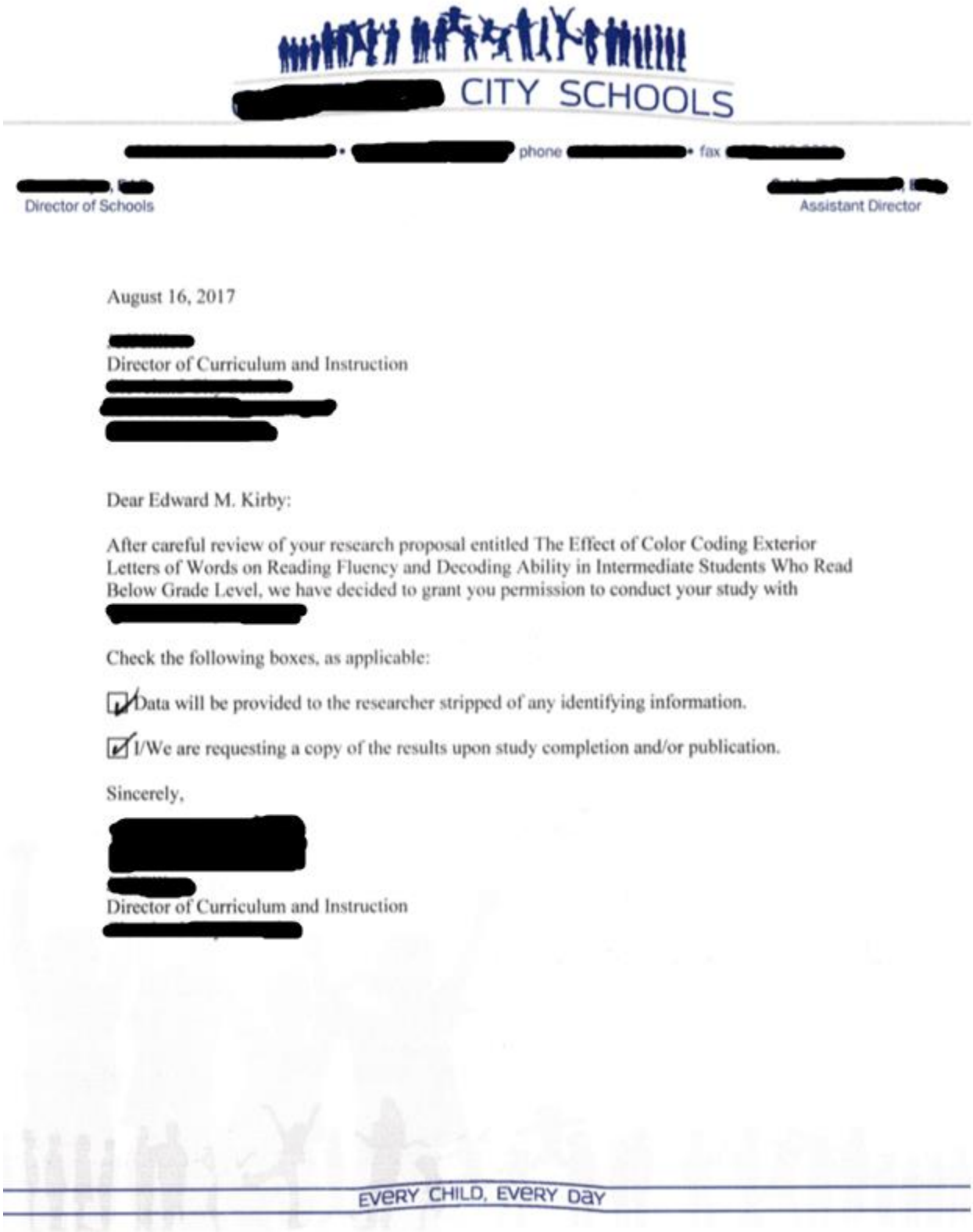
APPENDIX J: School District Approval



[redacted] CITY SCHOOLS

[redacted] • [redacted] phone [redacted] • fax [redacted]

[redacted], [redacted]
Director of Schools

[redacted]
Assistant Director

August 16, 2017

[redacted]
Director of Curriculum and Instruction
[redacted]

Dear Edward M. Kirby:

After careful review of your research proposal entitled The Effect of Color Coding Exterior Letters of Words on Reading Fluency and Decoding Ability in Intermediate Students Who Read Below Grade Level, we have decided to grant you permission to conduct your study with [redacted]

Check the following boxes, as applicable:

☑ Data will be provided to the researcher stripped of any identifying information.

☑ I/We are requesting a copy of the results upon study completion and/or publication.

Sincerely,

[redacted]
Director of Curriculum and Instruction
[redacted]

EVERY CHILD, EVERY DAY